# SCIENTIFIC AMERICAN

## No. SUPPLEMENT 557

Scientific American Supplement, Vol. XXII., No. 557. | NEW YORK, SEPTEMBER 4, 1886. | Scientific American Supplement, $5 a year.
Scientific American, established 1845. | | Scientific American and Supplement, $7 a year.


## RAISING THE WRECKED STEAMSHIP PEER OF THE REALM.*

THIS vessel, a screw steamer of 1,813 tons net register, and about 300 ft. length over all, laden with 2,600 tons of coal, ran on the rocks on the east side of Lundy Island during a fog on February 11, 1885. Her position was a dangerous one, as shown in the accompanying diagram, Fig. 3, being within 30 ft. of perpendicular cliffs more than 200 ft. high, where it was impossible to land; the only landing place on this little island is at the southeast corner, and is approachable only in fine weather. After careful examination of the wreck, although she had been given up as a total loss, the writer was confident, from his experience in the successful raising of several previous wrecks, that she could be profitably raised; and on July 13 he was commissioned to undertake the operation, which was carried out according to the following plan: The after part of the vessel being double-bottomed throughout its length of 80 ft., as shown in the longitudinal section of the vessel in Fig. 1, the water neither rose nor fell so fast inside as the tide outside. In this part it was considered that the leakage could be kept under by two 8 in. centrifugal pumps, P P, after throwing overboard a large quantity of coal so as to lighten the vessel and to form a well from which the windbore of the pumps could draw, as shown in Fig. 1. Amidships it was decided to do nothing beyond securing as firmly as possible the bulkheads fore and aft of the space occupied by the engines, boilers, and coal bunkers; and to allow the water in this space to rise to its level. Throughout the 142 ft. length of the fore part of the vessel, from the boiler room bulkhead to the stem, it was decided that the coal stowed in the hull must be platformed over, as shown in Figs. 1 and 2, with a timber deck strong enough to serve as a new bottom and to keep the wreck afloat with the assistance of two 8 in. centrifugal pumps, P P.

For carrying out these operations, the steamer Hoy Head was chartered, and on board her were placed four 8 in. centrifugal pumps, with engines and boilers for working them; also the whole of the timber for platforming the fore part of the wreck, and a large quantity of other materials and appliances. Everything was so arranged that what was first wanted was uppermost, and was easily got out by the aid of the steam winches. The Hoy Head was also fitted with the requisite accommodation for the workmen, fresh-water tanks, cooking appliances, etc.; she thus served during the whole of the time both as workshop and home for all the men employed on the work. The tides had to be carefully considered, and every advantage taken of them when at their lowest, inasmuch as very little could be done during neap tides. At the lowest tides there was 12 ft. of the wreck under water at the stem and 21 ft. at the stern, as shown in Fig. 5, and also by the sloping water line in Fig. 1; but only for a short time, as the tide falls and rises very rapidly; at high water her masts only were to be seen, the highest high water line being about 29 ft. above the lowest low water line, as shown by Fig. 5. As soon as the rising tide drove the men from the wreck, they occupied themselves on board the Hoy Head in preparing the materials for the next ebb. Whenever easterly winds prevailed, these prevented any work from being done upon the wreck, and on some occasions the Hoy Head had to go for refuge to Ilfracombe.

Operations at the wreck were commenced on July 24, 1885, and continued until the 30th, when they had to be suspended on account of bad tides. Work was resumed on August 5th, and by the 12th the platforming was completed on the top of the lower stringers in the fore part. With the aid of the steam winches a large quantity of the coal was thrown overboard from the aft part, as shown in Fig. 1, and some also from the fore part when the tide was down, and all heavy weights to be placed in the wreck were deposited in almost exactly their intended positions, where they were then quickly made secure.

The platform beams of spruce pine 10 in. square were laid transversely on the top of the coals in the fore part of the hull, being placed 4 ft. apart, as shown in Figs. 1 and 2. Each was in two halves with a long scarf joint well bolted togther. The advantage of this plan was that they were easily handled and got in between the iron stanchions, and fixed in their places more expeditiously. From dimensions taken at low tide the several pairs of halves were prepared beforehand on board the Hoy Head away from the wreck while the tide was up, during which time the men were kept fully employed in getting ready the materials for the next ebb. The platform or deck was made of longitudinal planks of spruce pine, 11 in. wide by 3 in. thick, nailed down upon the beams, and further held down by a transverse plank of the same size laid over them at each beam. Upon this

FIG. 6.

plank were footed the upright timber shores, some of them 10 in. × 5 in., and the rest 11 in. × 3 in., each firmly fastened at bottom between two chocks of wood nailed to the plank and to the shore. The upper ends of the shores were securely tongued to the ship's iron beams. About 2 ft. above the center of the upright shores a connecting batten, 3 in. × 1½ in., ran across the ship, securing all the shores to one another in each athwartship row. The spaces between the iron frames at each side of the ship—most difficult places to make water tight—were each filled with a wooden chock, well driven in and calked, and an upright shore was fixed on each of these chocks, with its top end bearing under the deck above, as shown in Fig. 2, so as to prevent the slightest upward movement of the chock. Over the chocks and round the frames was laid a body of best Portland cement, 3 in. thick, as shown at C, Fig. 2, which set hard and made a most complete water tight job. In way of the hatches were placed additional transverse beams, as shown in Figs. 1 and 2, for taking the upward pressure of the shores in these places. As the platform had to be fixed so low down in the wreck, there was very little time in each tide for carrying out such a large undertaking. Nevertheless, the work was successfully and speedily accomplished, principally through the efficiency of the arrangements adopted as above described, and without the aid of divers for any part of the operations.

After the platform had been calked and finished, the two iron pump wells, W, were fitted in it, one in each of the two compartments into which the fore part of the ship was divided by the iron bulkhead, A, Fig. 1, and a hole was cut through the bulkhead for allowing each well to get an equal share of water. When all the work had been tested, two 8 in. centrifugal pumps, P P, were placed on the main deck, one to draw from each well. So complete was the workmanship found to be, that the pumps were not required to work more than half their time during the tedious voyage of sixteen hours from Lundy Island to Cardiff.

On the morning of the 14th of August it was determined to make the attempt to raise the wreck. With the receding tide, steam was got up in the four deck boilers, B, Fig. 1. Before break of day the wreck was felt to move slightly with the rising tide, and at 5:45 A. M. she was completely afloat. After another careful examination all round, the tugboats received the signal to tow, and in two minutes she was afloat in deep water, towed by four powerful screw tugs, as well as by the steamer Hoy Head made fast alongside her, as shown in Fig. 3. A speed of 7 knots per hour was maintained until abreast of Ilfracombe, and then a slower rate up channel to Cardiff, which was safely reached at 10 P. M. All on deck being a complete wreck, with the bulwarks all swept away, the freeboard amidships was only 21 in. in coming up channel. The displacement with this amount of freeboard was 4,780 tons, being the weight of the vessel herself and all she contained; and the displacement up to the deck being 5,180 tons, there was therefore a surplus buoyancy of no more than 400 tons, forming a remarkably small margin for bringing the wreck safely up channel.

After discharging in the following week the remainder of the coal in the after hold only, the wreck was safely docked in one of the drydocks of the Mountstuart Shipbuilding Graving Docks and Engineering Company, in Cardiff. The hull had become coated with large quantities of barnacles and seaweed; and these having been cleaned off, it was found that her keel, bottom shell plates, frames, and floor plates were broken in a great number of places for about half her length, affording full scope for the water to flow in and out freely, and thus proving the platforming to be the best method that could have been adopted. On carefully examining the hull after being docked, it was very gratifying to find that, although the wreck had been exposed to much severe weather, she had not strained a single butt or rivet in her topsides, the whole of the damage to the hull being below the bilges. Her rudder and sternpost being broken and useless, she had to be steered by manipulating the tugs towing her up to Cardiff. As shown in Fig. 1, the heavy seas rolling over her had completely smashed in the after deck, as also the bridge, and the engine and boiler casings, etc.

In addition to the execution of the necessary repairs, all of which were carried out in conformity with the requirements and under the supervision of Lloyd's and the Board of Trade, the steamer was thoroughly overhauled and remodeled internally. Having been completed, as shown in Fig. 4, under the new name of the Dunbar, she left the graving dock on the 11th of January, 1886, for her trial trip in the Channel, which went off without a hitch, and was in every way satisfactory.

FIG. 1.

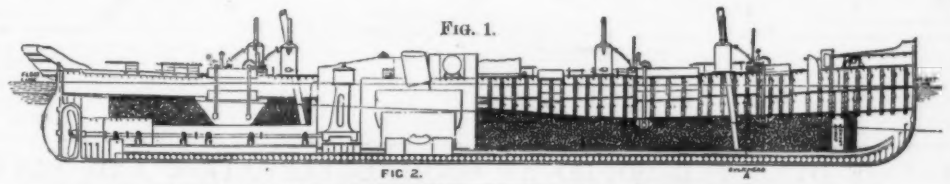


FIG. 2.

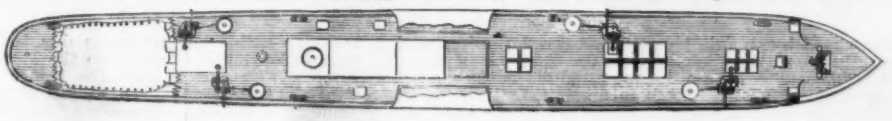


FIG 3

FIG.4

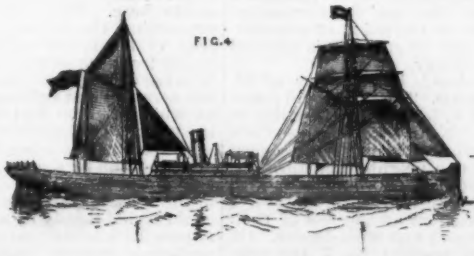
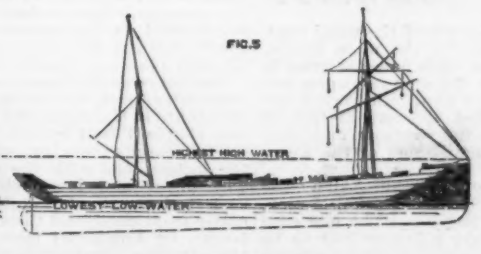


FIG.5




RAISING THE SUNKEN STEAMER PEER OF THE REALM.

A LOG of Tennessee poplar, 82 inches in diameter and 21 feet in circumference, was recently sawed on the band mill of the Nashville Lumber Company, at Nashville, Tenn. The log yielded over 3,000 feet of lumber, the widest plank being 58½ inches.

* Paper read before the Institution of Mechanical Engineers, by Mr. Thomas W. Walles.—*The Engineer.*

## THE LUIZ I. BRIDGE AT OPORTO.

OPORTO, situated in the center of a great agricultural country, is the most commercially active and richest city of Portugal. It extends along one of the banks of the Douro, the other of which is occupied by the city of Villanova de Gaia, where are located the principal port wine warehouses. The two cities, which together contain 150,000 inhabitants, formerly had no other means of communication than an old suspension bridge, which was constructed half a century ago by a Frenchman named Lucotte, and which was only middlingly safe. The erection of a rigid bridge seemed to offer great difficulties, seeing the great depth of the river and the nature of the bottom, which rendered the construction of a pier midway between the banks almost impossible.

A solution of the problem was still being sought when the construction of the neighboring Maria Pia bridge demonstrated the possibility of throwing metallic arches over wide spaces. It will be remembered that the span of this bridge's arch is 525 feet.

The government therefore adopted a like solution, and, in order to satisfy the interests of the upper and lower parts of the cities, decided that the bridge should have two platforms, one situated 160 feet above the other.

The contract for the construction of this work was put up for competition, and was finally awarded to Mr. Seyrig, representing the Willebraeck Society. The bridge, which has just been finished, may be divided into three distinct parts, to wit: the upper platform, the supporting arch, and the lower platform.

*The Upper Platform.*—The total length between abutments is 1,378 feet. The upper flooring consists of three parts, two lateral ones supported by straight lattice girders, and a distinct central one, 203 feet in length, connecting the two others. The center of this flooring is 2,040 feet above low-water mark.

The two main girders that support the flooring are 15 feet apart from axis to axis. They are 16 feet in thickness, and are formed of simple T members, and of a simple lattice of stiff bars. At the lower part, and in the vertical plane of the uprights, there are wind bracings for giving the necessary rigidity. At the upper part such rigidity is secured by the arched plates that support the roadway, and that constitute the best wind bracing. The total width of the platform is 26 feet. It is partially supported by brackets, that project 5½ feet beyond the girders. The roadway is paved with wood, and the sidewalks with flagstones.

The extremities of the two lateral parts end toward the center upon one of the upper cross-braces of the main arch, and are fixed immovably to it. The other points of support are the trestles on the haunches of the arch, the metallic piers, and the abutments, upon which latter expansion is provided for by the usual apparatus.

*The Metallic Piers.*—The piers are of the usual type. Their only peculiarity resides in the main braces, which have the form of a cross, with unequal arms in pairs. The two piers nearest the arch rest upon masonry foundations about 60 feet above the lower roadway. They contain an arched aperture 26 feet in width, to afford a passage to the roadway, and they support the extremities of the girders of the lower platform.

The laying of the masonry was facilitated by the nature of the ground, which consists of granitic rock. Yet, on the Oporto side, this latter was not met with everywhere, and supplementary masonry had to be substituted for it. The upper part of the foundation is reached by means of well-holes provided with ladders, and to which access is afforded by doors at each side of the roadway. These wells likewise communicate, through small tunnels, with the anchorages of the piers.

*The Main Arch.*—This is the most important part of the structure. It supports both of the platforms over the entire width of the river, and its span is at present the largest one that exists, it being, in fact, 566 feet. The thickness of the arch at the key is 26 feet, say $\frac{1}{21}$ of the pitch. This thickness continues to increase down to the springing, where it is 55 feet. In order that the stresses of the wind may be resisted, the two trusses are not parallel, but are spread 52½ feet apart at the springings and 19½ feet at the keypiece.

In the Maria Pia bridge,* the form of the arch is different, it being thicker at the key than at the springing. The reasons that led Mr. Seyrig to adopt the contrary arrangement are as follows: The Maria Pia bridge is designed for carrying a railway. The weight of the arch per current foot is inferior to the accidental overcharges. The result is that the bending moments in the center of the arch are very important with regard to compression alone. This part should therefore be given as great a thickness as possible. On another hand, the breadth of the extrados is only 13 feet, and in order to resist the wind's action, it would therefore have been necessary to give the pieces very wide sections, if the widening of the intrados had not contributed to a better distribution of the metal, and a certain amount of saving. With the Luiz I. bridge the conditions are different. The weight of the two floorings, joined to that of the arch, is, on an average, 13,400 pounds to the running foot, while the two test overcharges together amount to only 2,600 pounds per running foot. The asymmetrical arrangement of these overcharges, then, had no longer the same bending effects toward the key, and it became possible to diminish the thickness of the arch without detriment. In the second place, the space between the two arches is here much wider, it being 19½ feet at the extrados, and the effect of the wind is overcome by a section having a greater thickness than in the first place.

Then, again, Mr. Seyrig thought, as regards looks, that an arch that increased at the springings would produce a more favorable effect than would one resting upon points. Finally, Mr. Seyrig offered another argument: The arch, on increasing, permits of uniting at the springings the two systems of wind-bracing that are found in the successive planes of the intrados and extrados panels. This is necessary for transmitting stresses to the points of support. Now, as it was here necessary to provide for a roadway 26 feet wide, the latter would have been completely cut off by the wind-bracing. The great thickness of the arch at the springings permitted of overcoming this difficulty by raising the intrados wind-bracings, starting from upright No. 1, in order to unite them with those of the extrados at the summit of the upright at the springers. The passage is thus rendered free, and the stresses are transmitted to the upright at the point of support. The transmission to the points of support is effected through a large entrance gateway.

The latticework of the girders is in the form of St. Andrew's crosses, with uprights. The upper and lower chords are in the shape of a V, formed by the union of two simple T half chords. Nearly midway between the two chords there is a series of irons that connect the lattice bars with the two neighboring uprights. The upper and lower chords are connected with each other at the springings by the gateways above mentioned, and throughout all the rest of their length by horizontal traverses and wind-braces. On the extrados, starting from upright No. 7, the cross braces serve as a point of support for the girders of the upper flooring. In the plane of each upright there is a much less important vertical wind-bracing.

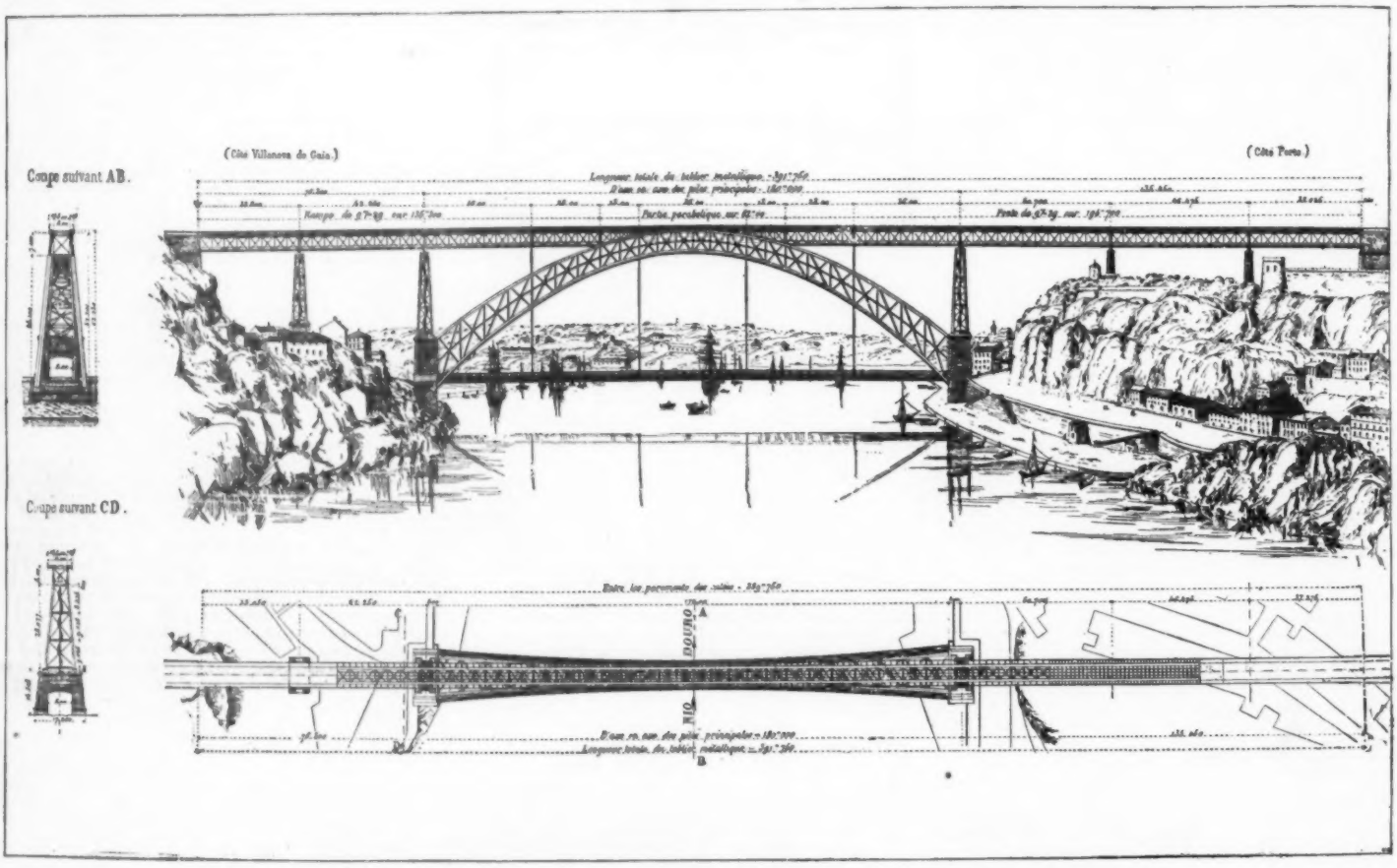
The arch rests upon the masonry through steel rollers placed in steel coussinets, which themselves rest upon cast iron imposts that distribute the pressure over the masonry. The two arched trusses are connected near the imposts, in the plane of the gateway, by strong transverse girders, to prevent the rollers from being pushed out through the inclination of the trusses.

*Lower Platform.*—The lower platform is divided into five bays by the suspension rods. It consists of two lattice girders, spaced 29½ feet apart from axis to axis and 10½ feet wide between chords. The members of these girders are asymmetrical, the top one having a 10 inch and the bottom one a 3¼ foot web. The uprights are in the interior, and those that correspond to the suspension rods are strengthened. These consist of a triple web, four angle irons, and a flange, and are braced by St. Andrew's crosses and a cross-brace located 26 feet above the roadway. The floor beams are about ten feet apart, and five rows of longitudinals receive the hollow plates of the roadway.

In the first project, the main girders were to have been jointed at three points, on account of the changes in level experienced by the points of support due to the asymmetrical overloads of the upper platform. The administration, however, preferred continuous girders, deeming that resistance to the wind ought to be the chief thing to be considered. The platform alone, without the aid of the rigidity of the suspension rods, is capable of resisting the wind. This result has been obtained by strengthening the main girders, which then operate like the members of a horizontal girder formed of themselves and the roadway floor. The stress due to the wind is therefore transmitted directly to the abutments, where shoes are arranged against the masonry that permit of expansion, but prevent all lateral motion.

*Erection of the Bridge.*—The mounting of the two parts of the platform was done in the usual way. The process employed in mounting the arch is very interesting, because of its novelty. Two metallic cables were stretched across the river, and the extremities of these passed over sheers that moved transversely with respect to the bridge, and that rested upon the platform that had been put in place. These cables were anchored to the platforms, behind the sheers, and over them ran small carriages provided with a guide pulley. Each carriage was at once fixed in the position desired by two cables with which the base of the sheers was connected. At the same place were situated the windlasses, whose cable passed over the carriage pulleys, and ran down to the river, to be fastened to the arch pieces that had been brought in boats. The heads of the sheers were fastened in pairs to the top of a pyramidal framework, firmly connected with the platform at its base. By varying the length of the rope connecting the framework and sheers, the apices of each of the latter could be moved toward or made to recede from the axis of the bridge, and thus move the hoisting cable to the same extent. It will be seen that this arrangement sufficed to allow every point of space to which a piece had to be brought to be reached by the hook of the hoisting cable.

The windlasses being thus stationary, it was easy to actuate them by a motor. Here the selection of a gas engine was indicated, seeing the intermittent character of the work and the convenience of using a fuel that could be led simply by a pipe. The operation of this apparatus was very satisfactory. In a short time, the workmen became sufficiently accustomed to the maneuvers to bring the heaviest pieces (of about 6,500 pounds) to their positions, and to a height of 195 feet,




BRIDGE OVER THE DOURO AT OPORTO.—ELEVATION AND PLAN.

* Described and figured in SUPPLEMENT, No. 90.

in from 30 to 35 minutes. All the parts of this hoisting apparatus, the sheers as well as the framework, were of metal. The cables were of steel.

The mounting of the arch was begun by placing the rollers in their sockets, and afterward superposing the vertical pieces connecting with the gateway. The first of these were so fixed to the masonry as to leave only sufficient space to effect the riveting, and then straightened still further, after the riveting was finished, so as to regulate the direction of the following pieces of the arch. When once the gateways were finished, the regular mounting was begun by portions of intrados. After forming the first truss, the work could not be carried on without a support, as the traction upon the masonry of the abutment pier became too great. A cable was therefore connected with the first truss, and made fast to a beam over the upper platform, in the axis of the metallic pier. Panel No. 1 was then finished. When truss No. 2 was reached, it became necessary to use six cables, as the load to be supported was about 250 tons. Beneath the intrados, at the desired point, there was a cast-iron beam, provided with three channels for the passage of the cables, whose extremities were provided with steel heads, resting upon box-shaped beams placed back of the upright of the upper platform. In order that it might resist horizontal traction, the platform was solidly anchored by special girders that joined fixed points beyond the abutments.

The cables thus arranged allowed upright No. 4 to be reached. Then they were moved a second time, as the point sustained by them was now beneath the extrados. In this position they were 16 in number, as the maximum tension that they had to support was 365 tons, corresponding to the moment at which the closing of the arch at the crown had to be effected.

When point No. 8 on each side was reached, the distance apart of the two symmetrical points was measured and their level verified. It was found that the distance between such points was too small by 2 inches, and that one of the sides was 3 inches lower than the other. The lower arch was therefore raised to the proper level. When nothing remained to be done but to insert the key piece, another verification was made, when it was found that there was a difference in level of about 2 inches, and that the opening was too small by from 1¼ to 1⅝ inch. But it was discovered that the degree of separation varied with the different degrees of temperature during the day, it increasing in the morning from 1¼ to 1⅝ inch. Profit was taken of this circumstance to place the two last pieces early in the morning of Aug. 11 (1885). One of these was found to fit accurately, while the other was about 0·2 inch too large; but this difficulty was soon remedied.

The rapid placing of some cross-braces and the wind-bracing allowed it to be considered that the most delicate and important part of the work had been happily finished.

As soon as the arch was entirely closed, the mounting of the pieces of the upper platform was taken up, and, when this was finished, the hoisting cables were undone and the mounting of the lower platform was proceeded with.

After the suspension rods were in place, the operation of fixing the girders to them was begun Starting from the abutment piers, the very rigid lower chord was gradually carried forward from each side and suspended from the arch by cables, and on this was afterward superposed the lattice work and upper chord.

Objections have been made to this mode of mounting, that it is attended with danger; and it was remarked, apropos of the success of the Maria Pia bridge, that no storms occurred during its erection. This is an error. The conditions of security will be absolute if natural precautions be taken; and, moreover, it is easy to see that an arch based upon points of support very distant from each other, and held above by cables that draw backward, is placed under very good conditions of stability. Finally, experience demonstrates that fears of this nature are exaggerated. The Garabit viaduct, during the mounting of the large arch, was submitted, January 26, 1884, without damage, to a most violent storm, that caused the fall of the Jardes viaduct during the launching of it. Even at Oporto, during the construction of the Luiz I. bridge, after the arch had advanced some distance, two successive storms of great violence occurred. Some scaffoldings were carried away, and the sheers were righted, but there the effects of the wind ceased.

For this description, and the engravings, we are indebted to *Le Genie Civil*.

## THE BUILDING OF CRANK SHAFTS.

WITH the rapid increase which has of late years taken place in the dimensions of marine engines, a change has also come about in the methods of making crank shafts. The old fashioned wrought iron shafts have been partly replaced by those of steel, in order to get rid of the uncertainty which is always felt about the soundness and continuity of the metal in heavy built-up masses of wrought iron, also to reduce the size of crank journals and pins and connecting rod ends, and thus reduce the friction of the engines; the decreased weight of these parts when made in steel also helps slightly to increase the carrying power of the ship by keeping down the weight of the propelling machinery to its lowest limits.

The solid steel cranks which have replaced those of wrought iron have not in every case been successful, as several of them have failed after a comparatively short life by breaking at the junction of either the crank pin or shaft with the web. This trouble has been partly overcome by the use of softer steels and by the careful annealing of the forgings before being sent into the machine shops, and also by increasing the radius of the corners of the necks and pins, and lastly by paying better attention to the rigidity of the engine seats and adjustment of the bearings, so that the cranks may be only subjected to the stress necessary to drive the propeller, and not to any strains set up by bad workmanship.

To reduce this evil still further, built shafts were proposed, and scheme after scheme has been patented with the object of allowing the different parts of the crank shaft to be so independent of each other that no strain would be set up in them by irregular setting or wearing of the bearings, or distortion caused in any other way, and also that if one part should fail the whole crank need not be consigned to the scrap heap.

The most common method is to simply fasten the shafts and pins into flat slabs which form the webs, and, given good steel and workmanship, this method is probably as good as any. The usual arrangement of manufacture is to rough-machine the parts, fasten them together, and then turn the crank all over just as a solid forging would be finished; but a great deal of the cost of this operation may be avoided by the use of proper appliances in building up.

The following is a description of the method and tools used for building up the City of Rome cranks at Sir Joseph Whitworth's works, Manchester. The crank shaft is shown in Fig. 8, and is, perhaps, the heaviest in existence. Fig. 1. shows the crank pin, Fig. 2 the shaft piece, and Figs. 3 and 4 the web.

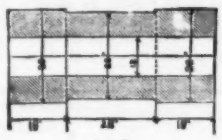


FIG. 1.

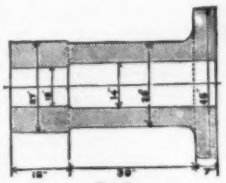
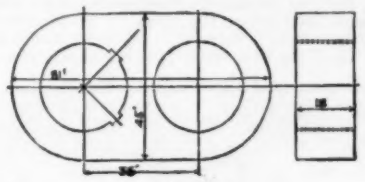


FIG. 2.



FIGS. 3 & 4.

FIG. 5.

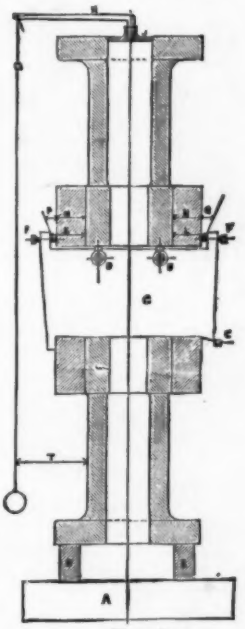


FIG. 6.

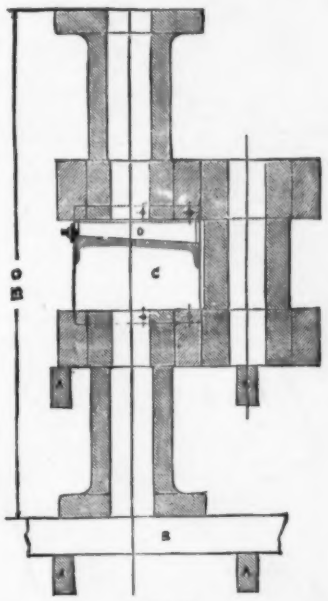


FIG. 7.

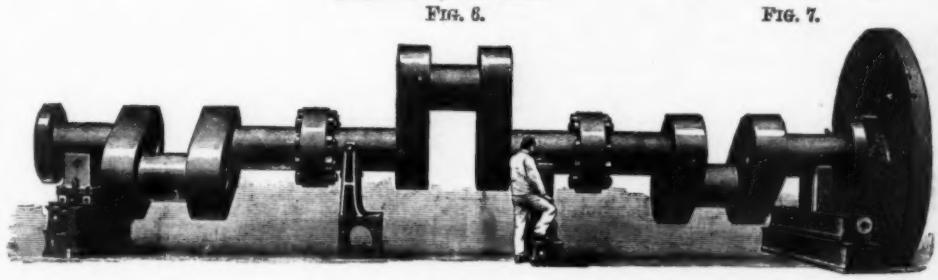


FIG. 8.

FIG. 10.

FIG. 11.

## THE BUILDING OF CRANK SHAFTS.

The crank is made throughout of fluid compressed steel, and was forged entirely under Sir J. Whitworth's patent hydraulic forging presses. The pins were forged hollow, turned to size and rough-bored, oil-hardened, and ground up true in the lathe by emery wheels, and polished on the bearings; they were thus completely finished before being shrunk in the webs. The webs were forged from very heavy ingots into slabs, the ends then punched and forged all round the eye on a mandrel. They were then planed, bored together in pairs, slotted round the ends, filed and polished. The shafts were forged hollow, and the collars afterward forged out to the proper diameter. They were then finish-turned on the parts fitting into the crank webs, rough-bored, and rough-turned all over, one-twentieth of an inch in diameter being allowed for turning and polishing, after the parts had been shrunk together.

The webs were keyed as well as shrunk on to the shafts, and so the real operation was to cut the keyways. For this purpose a gauge, R (Fig. 5), was made to fit the shaft ends, and the keyways cut in it. The shaft ends were then marked off, and the keyways planed and filed to suit the gauge, R. Another gauge, S (Fig. 5), was made to fit R, and keyways cut in it to suit. Two keys were then well fitted in the gauges, and the gauge, S, afterward turned so as to fit the holes in the webs (the amount turned off was of course exactly equal to that left for shrinkage); the keys were reduced in thickness by the same amount that the radius of S was reduced, and replaced in S. The ways were slotted in the webs to suit the gauge, S.

The keyways in the shafts now corresponded exactly with the gauge, R, and those in the webs with the gauge, S, thus enabling all the keys to be finished exactly to size, with the certainty that when the parts were shrunk together, the keys would fit accurately in their places.

The work of construction was carried out as follows: A A A A are four planed beams laid parallel to each other, and perfectly level; B B are two beams parallel and of the same depth, laid across them, and on these was placed one piece of shaft as shown in Figs. 6 and 7, and its height adjusted so that its top end stood above the top beams, A A, by an amount exactly equal to the thickness of the web when hot, so that when the web was laid across the beams its top side would be

exactly level with the end of the shaft, and as the web would gripe the end of the shaft sooner than any other part (on account of the shaft becoming warmer, and consequently larger, at that part than any other), they were exactly flush when cold; the same thing also holding good with the crank pin.

A pair of loose keys were dropped into the ways to insure them being opposite to each other when the web began to gripe the shaft, and soon afterward the loose keys were withdrawn and the proper ones driven in. The other web had now to be put on, so that the two pieces of shaft might be in the same straight line, and for this purpose a cast iron frame, C (Figs. 6 and 7), was made about ¼ in. thinner than the length of the crank pin, fitted with two steel wedges, D D, to adjust the distance between the crank webs, and fastened on the lower web by the screws, E. The wedges were adjusted by screws at their ends, so that the top of the web when hot would be exactly level with the top end of the crank pin. This being done, the web was removed and the shaft placed on the wedges. A center plate, J, carrying an arm, H, was then lightly driven into the end of the shaft, a plumb line attached to the end of the arm, and the shaft set by this means exactly central with the one below it, the distance, T, being then exactly the same in whatever position the arm might be placed.

Male and female gauges were made equal to K and L, and another pair to fit the crank web, M and N. A third gauge was next made equal to K—M or P, and a fourth equal to L—N or Q. It is thus manifest that if the web be laid on the frame in such a position that the gauge, P, will fit in the side for which it was made, and Q in the other side, between the web and the side of the frame, the hole in the web will be exactly central with the shaft beneath; but as the web is expanded when hot, and so makes the use of P and Q difficult, a feeler was made equal to P—Q or Q—P, whichever happened to be the greater; and after the web had been heated, dropped on the crank pin, and the shaft placed in it, it was so adjusted by the screws, F, that the difference in the two distances was always equal to this feeler, with the result that when put into the lathe for finish-turning, the two shafts were found in each case to be less than the thickness of a sheet of writing paper out of the same straight line. The loose keys were inserted, and when nearly cold the proper keys driven in their places as before.

*Shrinkage.*—One of the most important considerations is the amount of shrinkage to allow, and to determine the smallest amount which is absolutely necessary. Two plugs of steel were made, as shown in Fig. 11, to be shrunk in two rings, as shown in Fig. 10. On the first a thickness of three sheets of writing paper was allowed, and the ring, after being shrunk on and permitted to cool, was forced off by a load of 650 tons.

The second ring was bored $\frac{1}{64}$ of an inch smaller than the plug, shrunk on, and allowed to cool; the plug was then forced out by a load of 3,200 tons, the surfaces of the metal showing by the way they were torn the enormous amount of friction which existed.

Now $\frac{1}{64}$ of an inch is almost $\frac{1}{1000}$ of 18 inches, and so $\frac{1}{1000}$ of the diameter was decided upon as being the proper allowance for shrinkage for this and all other work of the same class.

The last mentioned plug and ring are shown in Figs. 10 and 11, which were engraved from a photograph.

The webs of the crank were heated to about 600° F., and when cooled to 400° they had commenced to gripe the pins and shafts, as shown by the holes in them being slightly decreased in diameter.

The weight of the shaft when the three cranks were finished and bolted together was 63 tons.—*Industries.*

## THE WATER SUPPLY FOR NEW YORK CITY.

By R. D. A. PARROTT.

So long as the work on the aqueduct progresses, a certain amount of assurance is felt by the people of New York that the future supply of water is being provided for. They also place reliance upon the statement that there is sufficient water in the Croton basin to afford a daily delivery of two hundred and fifty million gallons. The scheme, as the people see it, is complete, inasmuch as the required volume of water seems available and the proposed method of conducting it has proved safe in the past, and will probably answer in the future.

It will not be dwelling too much on the simplicity of the project to say that it may be divided into two distinct undertakings, storage and conveyance; but to go further, and say that the aqueduct is independent of the reservoir at Quaker Bridge, will immediately give a very different aspect to it, and eliminate a great part of the simplicity. Yet all the discussion from this time forward must center on the one question whether the aqueduct as now building can be utilized in its entirety in case the dam is not constructed. The promoters of this great work must be accorded the view that while it may be separated into two parts, aqueduct and reservoir, the combination of them is the only outcome that can be looked for. This position will be the most tenable, for, as will be seen, the idea of having the large conduit without the big dam is a result that the meteorology of the Croton drainage area does not justify. The fact that the aqueduct is being built without reference to any strain that might be brought upon it by a supply from an elevated watershed is evidence that the Croton has been considered all-sufficient, or else it is an admission that there is no other water to be had. The substitute for the big dam

MAP SHOWING PROPOSED WATER SUPPLY FOR NEW YORK CITY.

at Quaker Bridge, or rather the only alternative receiving any attention, is a series of smaller dams in the Croton basin, with a final recourse to the Housatonic for the balance needed.

If it is agreed that the above is the case, the time is at hand for showing objections to the dam—the engineers having decided that it will stand up and the politicians being agreed that the water will stand more pollution—because by and by the fact that the aqueduct is nearing completion will be brought up as a reason for securing the nearest water, and the dam will follow as an *unexpected* corollary.

From the publications of the Department of Public Works I have ascertained the rainfall at Boyd's Corners, the delivery of the aqueduct, and the waste over Croton dam for a period of ten years, 1872–1881; and from these data am able to show in the accompanying cut not only the quantity of water which may be relied on, but at what period of the year the surplus is offered. As to the capacity of the Croton watershed to furnish an adequate supply, there have been statements of estimates based on these and other data authentically made, ranging from 350 millions to a maximum of 400 millions of gallons per day. The lines in the cut prove that the larger quantity could never be obtained under any circumstances, while the smaller supply may be counted on if extensive storage is resorted to.

The method by which the Croton engineers figure that they can get 400 million gallons per day is hidden so deep in mathematics that no one outside of the profession will ever discover it; but still they should have credit for finding something more than the present delivery, although they cannot say how much. Presumably by the use of the same data from which the diagram is prepared, they have ascertained the mean monthly flow of the Croton River by dividing the annual flow in the years of heaviest rainfall by twelve. The result of course is a fictitious mean.

It will be noticed that the lines of rainfall and available supply indicate the mean of the records of the calendar months during the ten years, and consequently show what actually took place according to the seasons. The figures in the vertical column at the left represent thousand million gallons; the upper line shows the fluctuations and extent of the rainfall; the lower line shows the waste over Croton dam added to the delivery of the aqueduct; while the broken straight line represents the draught of the new aqueduct when conveying 250 million gallons per day.

The shaded space above the line of available supply shows the amount of evaporation and absorption. By imagining the available supply to be equally distributed through the months of the year, the reader can readily locate the fictitious mean on the diagram. It will not be far above the line showing the demand of aqueduct, so that it becomes obvious at once that the maximum capacity of the drainage area is not 400 million gallons per day, as claimed, but somewhere near 270 million.

A favorite plea for the big Quaker dam is that it will store the surplus of high cycle years, and thus maintain the supply during exceptionally dry seasons. But if the meteorological record is correct, every one can see that all the water which is available will have been stored previous to the first of June, at which time the line of supply crosses and falls below the line of draught. There is no question as to the fact that the surplus during March, April, and May will fill the reservoir, and that each spring season will thus provide all the water that can be impounded by the dam; and though there should occur a series of dry seasons, still upon the first of June each year the storage would nevertheless reach its maximum, thus displaying the hollowness of the high and low cycle phenomenon as a pretext for a dam of such small dimensions! But while proving the theory of catching water by a terminal dam as in itself correct, and calculated to afford a quota of 250 million gallons daily, it has also been ascertained that this will be accomplished by absorbing the entire drainage of the Croton watershed during eight months of the year, and two-thirds of it during the other four months; which consumption, added to the loss by evaporation, percolation, and local draught, will amount to 93 per cent. of the rainfall; the other 7 per cent. may flow into the Hudson. No other city ever practiced such discipline on a stream for running disobediently to the sea. It is evident the Croton water has sweetness not detected by taste, and potency not disclosed by analysis.

MAP OF QUAKER RESERVOIR.

The means of providing sufficient storage capacity have received attention before the consequences of holding back large bodies of water in artificial lakes have had due consideration; but certainly the sanitary question is the chief one in this instance, as in every other. A map of the Quaker Bridge reservoir is given to show, more plainly than can be done by description, in what sort of a basin the virtuous water is to obtain a better quality. The report of the survey contains information that should have condemned the reservoir at first, viz., that it has a flow line of seventy-eight miles. This length of swampy border is what is calculated to clarify the crystal raindrops. If the valley had bold sides and thin soil, the storage of water in it might be entertained, but the low mean elevation of the Croton watershed, besides the finding of loose dirt one hundred feet thick at the dam, would seem to indicate that the region was never intended for impounding such a vast body of water as is contemplated.

The artificial lake will be fifteen miles long, and the depth of water at the dam will be one hundred and seventy feet, which gives the bottom of the stream a fall of less than twelve feet to the mile. For every twelve feet that the water is drawn down there will be uncovered a lineal mile of the valley. This gives, however, a poor conception of what will happen when the great collecting reservoir is put to test, which will occur every summer if the graphic lines are right. This is the season when the rainfall is largely absorbed by the dry soil, evaporation greatest—as is made very manifest by the diagram—the demand most urgent, and the sun's heat capable of hastening vegetable growth as well as the decomposition of exposed aquatic plants.

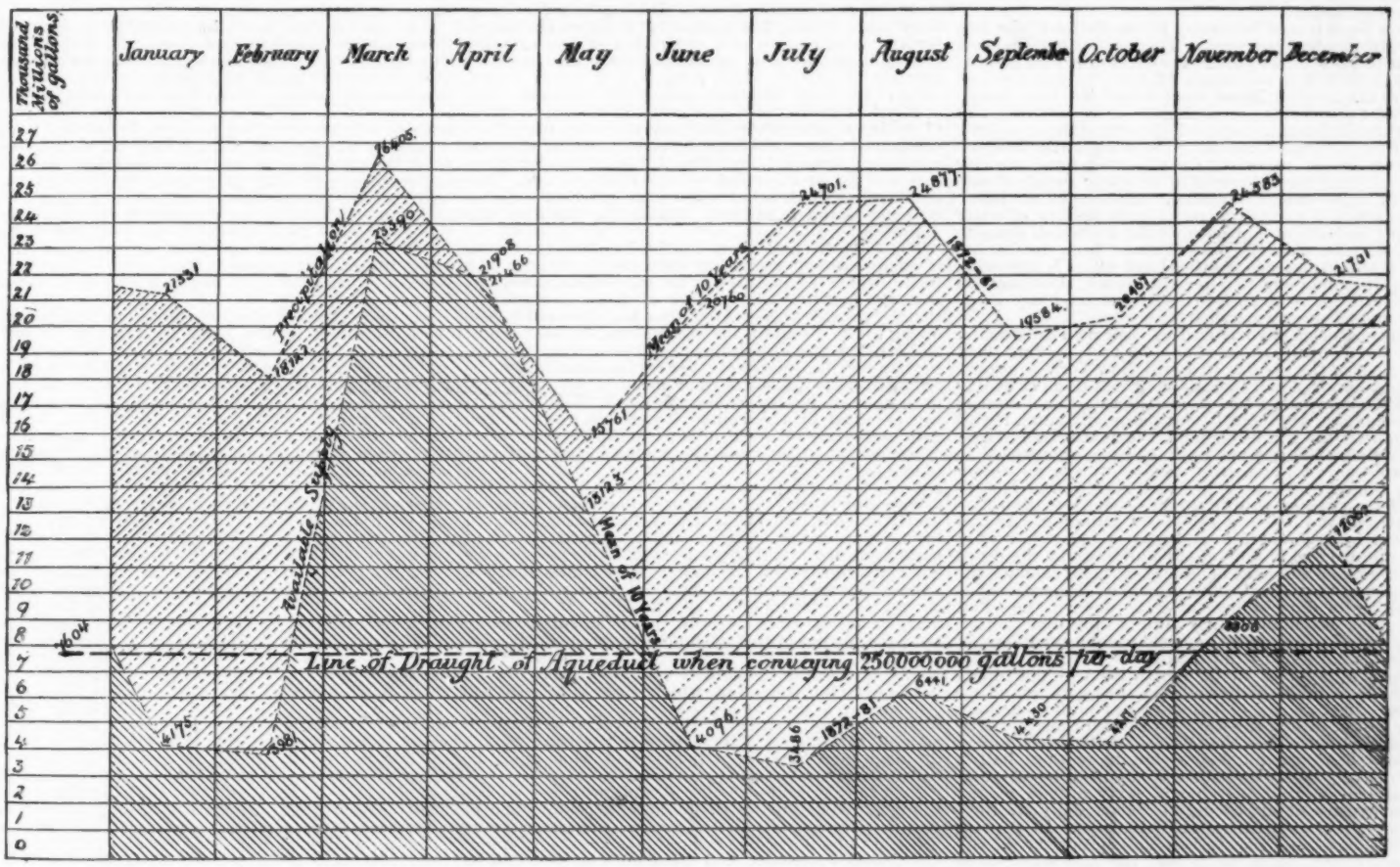
Commencing with June, the draught of the aqueduct will lower the surface of the water steadily, the land will reappear, slowly at first, and more quickly as the superficial area lessens. The scenery about the lake will be more hideous in September than in July. A fall of ten feet will expose 600 acres of bottom; twenty feet, 1,200 acres; thirty feet, 1,800 acres; when the water is level with the aqueduct, there will be 2,900 acres of pestilence-breeding mud dispensing foulness to the winds. The remaining 600 acres of the reservoir are below the gates, and consequently cannot be drained. The volume of water in this latter basin is eight thousand million gallons, and its depth at dam 113 feet, while the soil under it is reckoned to be nearly 100 feet thick. As ascertained from the record, the dam will be an absolute barrier to 83 per cent. of the mean flow-off, and obviously it will also keep back a proportional amount of the floating deleterious matter. There are but two alternatives for this high percentage of the captured drainage: it must either go to New York through the aqueduct or settle down in the blind pool. What the condition of this deep receptacle may be in a few years no one has ventured to predict; but it is the opinion of the engineers that the great average depth of the water will have a beneficial effect in diminishing the evaporation, which deduction requires that this incidental shortcoming of the great reservoir shall be credited with its *inert* influence. But the influence of depth on evaporation is not yet determined with scientific certainty; and the existing doubt should disparage the enthusiast in building a structure when it involves such a manifest breach of engineering practice as the retention of eight thousand million gallons of water from year to year, in the lowest part of a populous district, without any possible means of creating circulation or withdrawal of the sediment.

A circular reservoir, two and eight-tenths miles in diameter and twenty-seven feet deep, would hold the same quantity of water, and its flow line would only be nine miles long. This illustrative basin is displayed in the sketch to bring out the capacity of the artificial reservoir for accommodating riparian owners. Nature has been in this case inconsiderate enough to divide about eight times as many farms as are necessary, showing a predisposition to meddle in politics.

Not only will the evaporation from this body of water be up to the normal (amounting to two billion seven hundred million gallons during the year, or more than ten days' supply), but for many reasons it may be expected to be excessive. The extremely shallow shores—always presenting three hundred acres of water of less depth than five feet, and one hundred and fifty acres of less depth than two and a half feet, and so on—with deep surrounding soil will absorb the water and hold it in a condition for conversion more readily into vapor than if a rocky formation bounded the lake. The unusual loss from this source, besides the uncertain waste by percolation, can hardly be compensated for by the increase of watershed obtained by locating the new dam four and a half miles below the old one. All the conditions for rapid vaporization are present, giving the reservoir the character of a capacious evaporating pan rather than a magnificent settling basin of great average depth and minimum surface exposure.

The extensive length of flow line renders the possibility of ever making the reservoir acceptable as such, by revetment, as entirely out of the question. An artificial lake with seventy-eight miles border, all in fresh dirt, which at the caprice of the winds may encircle it with a roily girdle, will be a novel suburban attraction.

As we have seen, the flow-off will be confined to four successive months; and during the balance of the year, whatever flow-off there may be will go exclusively to New York. It is generally accepted as a good principle in hydraulics, to create thorough circulation by affording abundant inflow and outflow. In this case we happen to know exactly what volume of water will flow into the reservoir, and that between May and March not a drop will flow out of it, beyond what goes to the city. It would take a wide stretch of this hydraulic doctrine to bring the case in point within its



meaning, but perhaps the second discovery of the Croton has brought with it some new reasoning which will reconcile this apparent conflict between theory and practice. The simple question is, Does seventeen per cent. of the flow of a stream constitute an abundant outflow, and particularly when it is all limited to three months of the year?

When the big dam is built, the water will stand thirty-four feet deep over the top of the old Croton dam. This latter structure was very costly, and has served a good purpose since 1842, and will continue to be serviceable so long as the present aqueduct can be used. Its function will be destroyed when it is submerged by water backing up from the Quaker Bridge dam below. Thus, besides its many remarkable features, the project possesses wantonness, asserting, with little regard for economy, that the present dam must soon outlive its usefulness.

While the greater part of the Croton basin is in Putnam County, still, owing to its proximity and intended use, the matter under discusson concerns also the counties of Dutchess, Westchester, and New York. The area of these four counties is 1,580 square miles, and the aggregate of population 1,500,000, making an average of 900 people to each square mile. All of these people would be exposed to the ill effects of winds impregnated with noxious emanations from the drawn-off settling basin; more than 85 per cent. of them would be dependent on the same source for their water. The population of New York, Westchester, and Putnam counties will be more than 2,000 to every square mile before any water can be conveyed by the new aqueduct. These three counties contain 760 square miles. The drainage area of the Croton, together with that of the Bronx and Byram rivers, comprises at least 350 square miles within these same counties, showing that 47 per cent. of the given area is devoted to the impounding of pure and wholesome water for the domestic supply.

New York is now increasing in population at the rate of eight hundred per week. There is but one direction for it to grow in, and hence the opinion is very general that there will, in due course of time, be more people above the Harlem River than below it. One cannot conceive of the city preventing the early settlement of the three drainage areas noted without, at the same time, limiting its borders, checking its own growth, and defeating its best interests. On the other hand, the city cannot avoid the defilement of its water supply if suburban improvement continues. No scheme can be devised which is so at variance with the history of water supply, ancient and modern, as the one which seeks to provide more than the present quota from the Croton; and if the experience of other large cities is any criterion, the chief point to determine now is, How long will it be safe for New York to resist the tendency to go to a more distant watershed?

The engineers have figured to their own satisfaction that the dam will perform the task of holding back sufficient of the surplus to afford New York a supply for one hundred and sixty days (it will be a proud day for the metropolis when she can boast of voluntarily undergoing a five months' siege annually), and, if this alone were the simple demand, the matter might rest as settled. The people have become accustomed to pump water for domestic use, but this is no reason they should continue to do so. Owing to the lack of head on present supply, there is no less than five-eighths of the delivery raised by pumping. As this goes on quietly and in a small way at many houses in the uptown region and at all buildings in the down town region, there is, no doubt, a belief among the consumers that the Croton Aqueduct Department is fulfilling its duty in furnishing the water in the cellar, and that no municipality affords anything better. The cost of pumping by modern machinery differs, of course, according to the quantity. If thirty million gallons a day had to be raised 100 feet, machinery could be bought which would do the work at an expense of eight and a half dollars per million gallons. The cost of raising the water by several thousand little pumps cannot be less than fifteen dollars per million gallons, hence the admission that more than half of the delivery of the aqueduct is pumped by the consumers means that they handle sixty million gallons at an expense of one thousand dollars daily or three hundred and sixty thousand for the year. In drawing conclusions as to the justice and propriety of this annual charge upon the people, the fact must not be lost sight of that the water taxes are paid by a very small portion of the inhabitants, and that they also have to pay the additional running expense as above, after having bought machinery capable of raising sixty million gallons per day. What is it possible to do so long as the Croton basin is thought to contain the only water that will come to New York? Extensive pumping machinery and stand-pipes are talked of, and, no doubt, they would localize the necessary expenditure and constitute a popular sequel to the aqueduct and dam; but if it is shown that any increase of the supply from the present source is undesirable, then the question of pumping is done away with, because water from distant areas can be furnished under pressure.

I do not here allude to the supplies offered by the upper Hudson or Lake George, either of which would require the same outlay for machinery as would be found necessary in New York. Still these two sources are supposed in a vague way to be the ones from which the Croton can be replenished in the future. A system of supply which compels the raising of the water to such an elevation that it will travel say one hundred and fifty miles to its destination near tide level, and again raising it for use, will be an expensive one, particularly so as Ulster and Greene counties offer their high regions as substitutes for stand-pipes and duplicate pumping machinery, without charge for wear and tear!

It would avail nothing to call into question the purity of the present supply; but as the advocates of total absorption seem unduly persistent, it cannot be out of place to remind them that heretofore the proportion consumed by the city has only been one-third of the flow-off, while now it is proposed to consume nearly five-sixths of it.

The absence of pressure on the pipes necessitates a more perfect and elaborate equipment for extinguishing fires than if a pressure due to a hydraulic head of 300 ft. were constantly on them. The maintenance of the fire department in the year 1884 cost the city $1,600,000, and this outlay will increase, rather than diminish, every year, because, on the one hand, the extension of mains and service pipes increases the friction, while, on the other hand, the buildings are continually getting farther beyond the reach of the engines. The inadequate supply resulting from this lack of head in the lower part of the city has compelled the insurance companies to limit their risks, in consequence of which there is in the dry goods district alone between 100 and 150 million dollars' worth of property without any insurance whatever. It is small comfort for the owners of this vast interest to be told that there is no cause for anxiety, because in case of necessity a large volume could be furnished to the engines by letting more water down from the reservoirs, or that the annual quantity of water used for putting out fires is only two per cent. of the delivery of the aqueduct. The latter opinion has no more pertinence to the subject than if it was stated that the quantity was two per cent. of the flow of the Hudson River.

Notwithstanding these explanations, there is a well founded apprehension among insurance people that property down town is not secure against widespread conflagration, and no quantity of hand grenades, or steam jets, or too feeble fire engines will ever dispel it—nothing but the actual presence of water under pressure and in unlimited supply. The fact that risks are declined because of the deficiency of the water does not argue that the insurance companies are alone interested in remedying the matter, for whether the property is covered or not, the loss in case of fire would be the same. London would suffer if policies were in force, but as it stands now the loss would be *local*.

When the Croton water was introduced, in 1842, a reduction of forty cents on every one hundred dollars in the annual rates of insurance was effected. At this time the average height of the buildings could not have been over thirty-five feet above street level, while at present it is about ninety feet. During the intervening forty years the city has assumed a different character. By the introduction and perfection of the elevator system alone, the area of Manhattan Island has been increased one-third, which is equivalent to six square miles of territory, with an approximate mean elevation of fifty feet above the city of 1840. Hence the problem of to-day is altogether different from the one which was solved many years ago, by conveying the water in a masonry aqueduct, and distributing it under pressure due to an elevation of 115 ft. above tide. The scheme thus carried out was a success, because the requirements and conditions formed the basis of the undertaking.

The daily demand of one hundred gallons per capita is comparatively large, not only on account of the waste, which is equal to the actual consumption, but from the fact that the number of factories is proportionally greater in New York than in other cities, also owing to the draught for steamships, elevated roads, and construction of buildings. An idea of the misconception on this question of per capita demand may be obtained from the following remark of Nicolas Dean, president, in his report, December 31, 1852, viz.: "It was assumed by the commissioners that twenty two gallons per day for each inhabitant would be a liberal allowance, at which rate a city containing a population of two and a half millions might be supplied by an aqueduct of the proposed dimensions." During the intervening years the allotment has been increased nearly fivefold, and inasmuch as this unusual demand has been accompanied by an unprecedented growth of manufacturing establishments, while the people have enjoyed a remarkable freedom from epidemics, it would appear that to foster the one and secure the other should be the future policy of the city. If this summary of the existing state of things is substantially true, the project of to-day should comprehend the supplying of 400 million gallons daily from a district wholly apart from the Croton and having a hydraulic head of 300 ft.; instead of which there is a fatherless scheme for a *gravitation supply*, the terminal dam having its base 70 ft. below tide level and its lip high enough to stop all but seventeen per cent. of the drainage from forty-seven per cent. of what might be called the future metropolitan area.

Next to this is offered the idea of progressive damming. It contemplates the building of small dams at various points as fast as the storage is needed. There are said to be thirty-one natural lakes scattered about the Croton watershed, and these no doubt would in time be the sites of the artificial reservoirs. Such an arrangement of the malaria breeding grounds may be less objectionable than having them all concentrated at one point, still it would only be fair to let the people in the vicinity say whether they prefer diseases to be sporadic or epidemic!

The hydraulic engineers advocate the big dam because it forms the only means by which a large part of the precipitation can be secured; in fact, they admit that, without it, the area of watershed which could be utilized for storage purposes would be reduced from 360 to 200 square miles, which means that the flow-off would be augmented in this ratio, owing to the difficulty of impounding the rainfall in the more elevated portions of the watershed. Assuming this opinion as to area to be correct, the data already used for the diagram, showing the excessive loss by evaporation and percolation, will answer to prove that only about seventy-five million gallons could be provided in this way. The deficiency must be made up from the Housatonic, a polluted stream having its source and course beyond the jurisdiction of this State.

The desire to bring into notice the water courses of Ulster and Greene counties as affording a suitable supply for New York has made it necessary to state many of the acknowledged defects of the Croton system, because the mere suggestion of a new watershed is quite secondary to the importance of convincing the public that the present scheme is not based upon the demands of the city. While the criticism might be lengthened out and attention directed to other points, it will be sufficient ground for the rejection of the Croton if the statements as to quantity and the probable future impurity of the water are not disproved, and the requirements of the city are conceded to be fairly represented.

Esopus Creek has a course about fifty miles in length. It starts in the Southern Catskills, between Spruce and Panther mountains, at an elevation of 3,600 ft., and descends through five-sixths of this height in the first half of its course. Twenty-six miles from its mouth at Saugerties, but only fifteen in a westerly direction from the Hudson River at Esopus Light, the stream has an elevation of 500 ft. above tide level. Somewhere near this point, in the town of Olive, should be located the terminal dam. To convey the water to the aqueduct at Croton would require fifty miles of pipe conduit. Above the site of the dam there are 240 square miles in the Esopus watershed. Beyond the divide to the north are the head waters of the Schoharie Creek. Of this watershed 110 square miles can be drained into the Esopus by a tunnel eight miles long, under the Lexington and Westkill chains. Still farther to the north is the Batavia Kill, which drains 50 square miles, sufficiently elevated to permit of the water being diverted into the Schoharie by a tunnel three miles long, whence it would flow into the Esopus by the first tunnel.

These three drainage areas are indicated by broken lines on the map; the tunnels, by solid lines. A tunnel starting in the valley, at a place called Big Indian (1,210 ft.), and running northwest eight miles to Dean's Corners (1,344 ft.), would drain 130 square miles of territory, bringing Dry Brook, Bush Kill, and the head waters of the Delaware River into the Esopus. The combined area of these four drainage areas is 530 square miles. This country embraces many of the highest peaks of the Catskills, such as High Point (3,098 ft.), Wittemberg Mt. (3,776 ft.), Slide Mt. (4,205 ft.), Hunter Mt. (4,040 ft.). Sixteen elevations, eight of which are found on the profile of the Ulster and Delaware Railroad, along Esopus Creek, make the mean altitude of this particular watershed 2,100 ft. The land to the north and west of the Esopus divide has a greater mean elevation, and does not fall so precipitately as the land facing the southeast. By reason of this topographical feature of the range, the outlying streams as noted may be made tributary by tunnels above 1,200 ft. elevation, and, no doubt, both the Delaware and Neversink could be made to contribute, in addition, the flow from a thousand square miles.

Geology has done much for the Catskills in making them suitable as a gathering ground for water supply. The familiar sandstone and shale identifies the group as of the earliest origin, and the occurrence of the conglomerate of quartz pebbles locates it next below the coal formation. The strata are not tilted in any marked degree from the horizontal, but show a general regularity of position, conforming so well to each other in many cases as to give a banded and artificial appearance to the sides of gorges. From the town of Olive to the top of Spruce Mt., along Esopus Creek, and from Gilboa on the Schoharie to its source, near the Plaaterkill Mt., are to be noticed five sections of the mountain rock—greenish brown shale underlying brownish red shale; then reddish brown grit, reddish brown shale, and greenish gray grit, succeeding and alternating with brown or green slaty grit. Excepting a thin stratum of limestone conglomerate, there is nothing in the rocks that rain water will be likely to carry off in solution. Chance of percolation and subterranean drainage is lessened by the impervious character of the rocks in place, their horizontal position, and the steep inclination of the valley sides.

The mean temperature of the water taken from the Esopus will be at least six degrees lower than that of the Croton water, in consequence of the difference in latitude and elevation. When the rain-bearing clouds from the south strike the comparatively cold atmosphere of the high lands, their vapor will be condensed and swell the streams in the Esopus Valley. Winds approaching from the north, laden with moisture from the valley of the Mohawk, will likewise fall in temperature, and precipitate their rain in the Schoharie and Delaware. The region will be as prolific of thunder storms as heretofore, and it may be said that "Hendrick Hudson and his crew are at their game of nine pins" still. It is more than probable that the flow-off from these comparatively lofty areas will show an unusually high ratio to the precipitation; furthermore, there is a likelihood that the opposite sides of the ranges will contribute water from entirely distinct storms, and thus maintain a uniform flow down the valley to the terminal dam. The minimum flow from the four basins will exceed the draught of the city for many years to come; and if the separate areas may be brought into one by short tunnels, as designated, the time for resorting to storage will be long postponed.

Suffice it to say that the geological, topographical, physical, and meteorological features of these combined drainage areas are incomparably superior to those of the Croton in every particular.

Many months before the new aqueduct can be finished, and many years before the big dam can be completed, a pipe capable of carrying fifty million gallons per day can be constructed. The dam at Olive City, the pipe conduit to Croton, and the modification of the new aqueduct are only matters of engineering detail.

Whether the cost of securing a supply from the Catskills will be greater or less than that of one from the Croton and its adjuncts, is not of interest now. Relative cost cannot form a part of the discussion, unless both of the projects bring about identical results, and such a final coincidence between undertakings widely different in their inception and general character is beyond all possibility.

This, then, is the region for those in authority to bring within municipal control, for with it they can quickly replenish the deficient supply, gain the needed head for fire service, and secure a wholesome drinking water. Here are the four hundred million gallons that the city will ultimately require every day, if the ratio of manufacturing to her population is to be maintained. By no other means can New York make the risks on one hundred and fifty million dollars' worth of property acceptable to the insurance companies of the world. High up on these mountains, aside from the paths of development, and remote from the influences of thickly settled districts, is a park which the city may preserve as a collecting region for unpolluted water.

---

WHEN a paint brush is stiff and hard through drying with paint on it, put some turpentine in a shallow dish and set on fire. Let it burn for a minute until hot, then smother the flame and work the pencil in the fingers, dipping it frequently into hot spirits. Rinse all paint brushes, pencils, etc., in turpentine, grease with a mixture of sweet oil and tallow, to prevent them from drying hard, and put them away in a close box.—*Cal. Arch.*

[THE HUB.]

## GENERAL PRINCIPLES GOVERNING THE ACTION OF CARRIAGE WHEELS.

A WHEEL is a contrivance to utilize some of the principles of motion of a ball or sphere.

A ball or sphere moves upon a level surface easier than any other form of solid matter. This is because its center of gravity is not changed in its progress. If a ball moves upon a level surface, its center of gravity describes a line parallel to the surface. A ball is balanced in every direction when it is at rest. The power required to set it in motion is just enough to unbalance it. Like a pair of scales balanced with a ton weight on each end of the beam, a few ounces added to either end will move them.

A carriage wheel, in principle, is a slice from the center of a ball. So long as such a wheel moves uprightly upon its rim, it has the facility of a ball to move in two directions only. To keep it in this position an axle is put through its center. This adds friction to it, and also shortens the leverage by which it is propelled, from its rim to its center.

A carriage wheel has to do duty generally upon a common road, the best kind of which is the macadamized. A wheel sinks somewhat into the loose material upon the surface, which it has to surmount in its progress. This is called traction or rolling friction.

The rubbing of two substances together causes friction. It is the resistance to the motion of one substance bearing upon another. It increases with the weight or pressure of objects at their frictional contact, but not with the extension of the frictional surfaces.

If four blocks of wood or other material, of one kind and of similar weight, be placed one on the top of the other and dragged upon a board or other smooth surface, and the weight or force be noted that is required to pull them, and then, if the same four blocks be spread side by side and dragged upon the same surface, it will be found that the same weight or force will pull them. This shows that, if the surfaces in frictional contact be extended, but the pressure upon them be not increased, the resistance called friction is not increased. This law applies to axles.

Friction does not increase with the size of an axle, but a wheel loses power or leverage with the increase of the size of its axle, and also by increased weight.

To find the amount of resistance there is to two smooth plates of metal—such as an axle and its box, with a layer of oil between them—sliding upon each other, we proceed as follows:

Let AB in Fig. 1 be the plates, and AC a perpendicular to their two surfaces. Draw ED parallel to AC, and CD parallel to the plates, thus resolving the force DA into two forces, one, DE, pressing A upon B, and the other, DC, tending to make A slide toward F. It will clearly depend on the strength of the friction between A and B how far the force DA may be made to decline from the perpendicular without actually causing A to slide upon B.

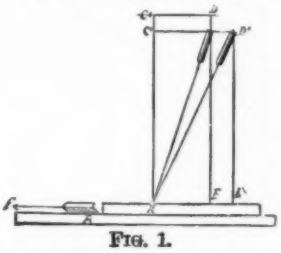


FIG. 1.

Suppose the pushing force be brought into the position of D'A, and as A is just ready to slip on B; then, since D'E' and C'A are the forces pressing together A and B, and D'C' and E'A the forces tending to produce motion, D'C' will be $\frac{1}{10}$ of C'A. D'AC' is called the limiting angle of resistance of the surfaces A and B. If 500 lb. be the pressure, made to decline until it reaches the limiting angle of resistance, $\frac{1}{10}$ of 500 = 40 lb., or 0·08, would be required to pull the plate A on B on a dead level. The figure 0·08 is called the coefficient of resistance of these substances, and may be used to compute the friction of oiled metals.

The actual friction going on within an axle-box is more than 0·08, because we have not taken into consideration the rubbing of the washers on the axle end and collar, and the gather of the axle; but these are so little in good-running wagons that they may be neglected.

Traction, or the resistance to the progress of a wheel, upon a macadamized road has been practically proved to be about $\frac{1}{30}$ of the load. The power required to move 500 lb. would be 17 lb. Upon a good, hard road, therefore, a horse will require to pull at the rate of 40 + 17 = 57 lb. to draw 500 lb. on free-running wheels.

### THE POWER OF A WHEEL.

If an obstacle, say 4 inches high, be in the way of a four-foot wheel, the center of gravity will have to be raised 4 inches to overcome it. The lever to do this with is just half the height of the wheel, viz., 2 feet. This lever is of the third order of levers—that of having the power come between the load, which is lifted, not pried, and the fulcrum. Neglecting any momentum the wagon may have, and calling it a dead lift, by the law of virtual velocities "the power multiplied by the distance it moves vertically or in a right line equals the load or weight multiplied by the distance it moves vertically or in a right line." See Fig. 2.

In Fig 2, let the power be at A, the axle; the load 500 lb.; and D be the height of 4 inches, to which it has to be raised. A will move through the curve AB, while the center of gravity is raised upon D; then A, the power, will be plumb over it. The power A will have moved forward the length of from A to C, and up from C to B upon the resultant curve, AB. It is clear that the length from A to C is just ¼ the diameter of the wheel, equal to twelve inches. Now, according to the law of virtual velocities, it is with a right line from A to B, upon which the force was truly effective, that we have to do; and this is found by taking the square root of the base line AC times the square root of the upright line CB, which is $\sqrt{12^2 + 4^2} = 12{\cdot}65$. Now the load, 500 lb., times the height, 4 inches, which it is to be raised, equals 2,000, which should be equal to the product of 12·65 times the power. If we divide 2,000 by 12·65 we have 158 lb., which is the force required to put 500 lb. upon the obstacle in front of the wheel.

This can be proved by the inclined plane, EG. Let a base line from the point E be drawn, equal to the length of the circumference of the wheel, which is its diameter, 4 ft., multiplied by 3·14169 = 12·566. Now, as the incline rises 4 inches to the foot, as is shown by the object in front of the wheel, 4 inches high and 12 inches from point of gravity upon the ground at E,

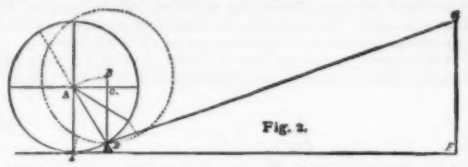


FIG. 2.

therefore, an upright drawn upon the extremity of the base line at F, to be of the same proportions, will require to be 4 times $\frac{12{\cdot}566}{12}$ in height, which is 1·0472 × 4 = 4·1888 ft. high. The length of the incline to this base and upright equals the square root of the base line times the square root of the upright:

$$\sqrt{12 : 566^2 + 4 : 1888^2} = 13{\cdot}20 \text{ feet.}$$

The power of an inclined plane is as its length is to its height; therefore the load multiplied by the height of the upright and divided by the length of the inclined plane, which is 500 × 4·1888 ÷ 13·20 = 158 lb., the power required to sustain 500 lb. upon it.

Now, by adding the friction of the axles, and traction, already found to be 57 lb., to 158, we have 215 lb., which is the force a horse will require to exert to haul 500 lb. up such a slope of a macadamized road. This 500 lb. means all that bears upon the axle-boxes, that is, the total weight of wagon and load minus the weight of the wheels.

### THE MOTION OF A WHEEL.

That the part of a carriage wheel above the axle moves faster and through more space than the part below it, is because this kind of wheel is a lever of the third order. Such a lever has the power applied between the weight, which is to be pushed, pulled, or lifted, and the fulcrum; the same as in raising a ladder. Imagine two spokes in a line to be a ladder; the lower end is on the ground, the force or hand being exerted at the hub; the point on the ground, which is the fulcrum, remains stationary, while the upper end moves through a space which will be double the distance that the middle or hub goes. The rim being endless, each point as it touches the ground becomes a new fulcrum. A carriage wheel is thus called a perpetual lever of the third order.

In Fig. 3 the reader will observe that, while the point of spoke, A, moves to the ground at B, the

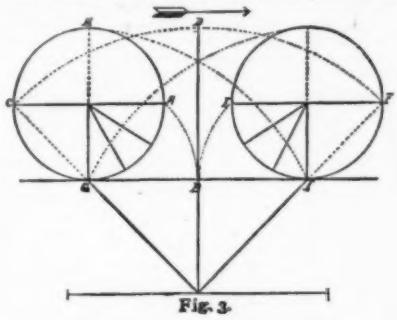


FIG. 3.

opposite end, C, of the spoke in a line with A goes up to D, and the line of spokes, AC, there coincides with the line BD. The wheel has now made a one-fourth revolution upon its rim, from G to A, upon the ground, GB. When it makes its next quarter revolution, B goes up to E, and D goes to F. Thus it is clear that the point A, on the dividing line between the upper and lower halves of the wheel, goes down to B, and up to E, while the point C on the same line sweeps through the great curve, CDF. The wheel has now made one-half of a revolution, and the line of spokes, AC, now coincides with the line EF. The upper part of the wheel has now become the lower, and, with the onward movement of the wheel, the same thing is continuously repeated.

To show the ratios in decimal notation of the curves which the points opposite in the lower and upper half of the rim of a wheel describe, or of their motions, would require the use of a calculus, which would be of no practical value here, as these curves are graduates—that is, having no center.

JAS. G. CAMERON.

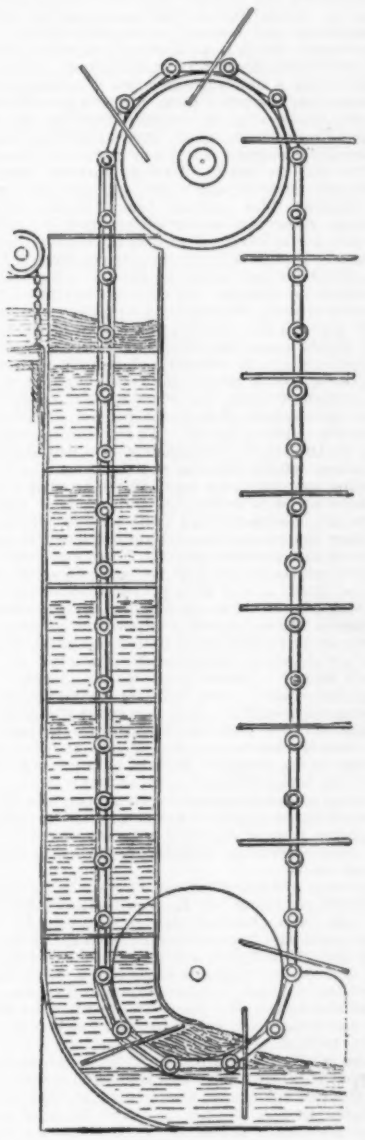
San Francisco, Cal.

## THE BREAKING OF GRINDSTONES.

IN his new annual report, Mr. Redgrave, chief inspector of factories, says: "Mr. Bartlett, Redditch, referring to paragraph of my report for 1884 in which I have expressed a doubt whether it were possible to prevent the breaking of grindstones used in the cutlery trade, has sent me a recommendation, which I am glad to mention for the information of users of emery wheels, especially grindstones. Mr. Bartlett says: (1) 'Lay in the stock of grindstones not later than the middle of July, in order that they may have ample time to dry in the sun and air. To do this they must be placed where both sun and air can get to them, and they must be put on their edges on pieces of boards, not on the earth, so as to avoid the absorption of any moisture. (2) As soon as dried thoroughly, they should be placed in the rooms in which they are intended to be used, or in a dry storeroom, and not be allowed to come in contact with soil or get damp again. (3) Before being used, each stone should be tested in a strong wrought iron testing box, and driven at a greater speed than when in work. (4) The stones above 9 in. in diameter should be hung with side chains or plates instead of being led on their spindles. By the adoption of this system, we have had no accident for twenty years.'"

## THE BALANCE WATER MOTOR.

FOR the balance water motor shown at the Inventions Exhibition, London, is claimed by the inventor, Mr. Sealy-Allin, an economy of not less than 93 per cent. The invention has for some time been undergoing an exhaustive test by Mr. Simon, the well known milling engineer of Manchester, and Mr. Sealy-Allin read a descriptive paper at the recent meeting of the National Association of British and Irish Millers, held in Dublin, which led to an animated discussion among the assembled millers. The claim of 93 per cent. efficiency is so extraordinary in itself that it is surprising it did not attract more attention from the jurors of the exhibition. So far as we remember, no one had before ventured to claim an efficiency of more than 80 per cent. for any water motor, while the best turbines were usually averaged at about 70 per cent., and undershot water-wheels at so little as 35 per cent.; hence a claim for 20 per cent. more than had hitherto been attained should have received more attention than it met with, especially when the inventor of the engine challenged the test. In England there are something like 6,000 water motors at work, driving flour mills mostly, and if we assume, as we may, that these return an efficiency of only 40 per cent., it is easy to see that there is a very wide margin for improvement. As Mr. Allin said in his paper, with falls of a height of 20 ft. to 25 ft. there



is a possibility of getting 60 per cent. from water-wheels and 70 per cent. from good turbines; but there are not many wheels, and still fewer turbines, that give such results even with a full supply of water. As most people know who have studied this question, among water-wheels an overshot gives the highest results; but, to quote Mr. Allin, we may say that "the overshot and the high breast wheel are actuated almost entirely by the weight of the water and their maximum possible efficiency is 60 per cent. This is a low enough figure, but on a suitable fall and with well constructed wheels something near that percentage, say 55 per cent., may be insured. The undershot wheel is, on the contrary, worked by impluse. Half the power is wasted in shock and unexhausted velocity, and after providing for the friction of the wheel, only about 40 per cent. effective return is possible, and usually much less is got. In the case of one wheel that I examined a few weeks since, with 50 theoretic horse power on a fall of 5 ft. 9 in., the efficiency was 26 per cent."

Taking, for example, a fall of 13 ft., an overshot wheel of 11½ ft. diameter, and a depth of 18 in. of water in the leat above, with the bottom of the wheel just clear of the tail water, and the gate raised 6 in., Mr. Allin says the water rushes out under pressure and instantly disappears in the mouth of the nearest bucket, and to any one standing by it seems as if it were actually on the wheel. A little reflection, however, will show that is not the case, that it is really only chasing the bottom of the bucket, which it does not overtake for some distance. You will see this is so if you consider the relative velocities of the wheel and of the water. The velocity of the wheel is the usual one of 6 ft. per

second, and the speed of the water issuing under a head of 18 in. is just under 9 ft. per second. In half a second, therefore, the bucket will have traveled 3 ft. To this must be added a start of 15 in. which it had of the water, as the depth of the bucket is 15 in.; and while the water must reach the bottom to produce any effect, the top must pass the water before it can begin to enter, just as you must pour in water over the top of a jug, if you wish it to reach its bottom. Adding, therefore, these 15 in. to 3 ft., we get a distance of 4 ft. 3 in. practically traveled by the bucket in half a second. But in the same half second the water would have traveled 4 ft. 6 in. It would therefore overtake the bucket bottom as nearly as possible at 3 ft. 11 in. from the outlet. Nor is any appreciable proportion of the loss of about 26 per cent. recovered, as you might suppose, from impact. Under no circumstances could more than one-third of its force be got, as the water strikes a body (the bucket) moving at two-thirds of its speed, and in the same direction, and then only if it struck full square against a flat surface, and was confined so that it could not break up. Instead it strikes a curve, and glances and eddies, and does not, in fact, settle down as a dwelling weight for some distance further. To produce the best results the quantity of water on the wheel should be nearly sufficient to fill the buckets; and if they are full, or nearly so, they begin to discharge directly they pass the center, and are empty before reaching the bottom. Mr. Allin, comparing the water-wheel and the turbine, says there can be no doubt that a really good turbine of perfect workmanship, and correctly designed for the volume of water and the fall it has to deal with, will give a higher efficiency than any water-wheel. The buyer, however, runs a much greater risk of getting an inefficient machine, because, even assuming—which is far from the truth—that all types of turbine are capable of giving 70 per cent., every individual turbine should be specially designed for the exact conditions under which it has to work. This is scarcely possible in practice, as turbine drawings and patterns are very costly affairs. The turbine has, however, the great advantage over the water-wheel that it utilizes the whole fall, for it loses nothing in taking or discharging the water; but it has disadvantages from which the water-wheel is free. It is not, however, the purpose of this article to discuss the relative merits of turbines and water-wheels, but rather to explain the construction of the balance motor, illustrated in the diagram, which yields something like 93 per cent. of the power expended on it. It consists of a shaft with a pair of wheels, over which pass a pair of chains, or, more correctly, series of links, between which are carried, attached by brackets, flat floats placed at intervals of one or two links apart. These chains pass down guides in the sides of the casing, and round pulleys at the bottom, which prevent oscillation. The floats are suspended centrally, so that the center of gravity of the whole series is vertically under a line connecting their points of suspension on the wheels. They, therefore, hang plumb and travel plumb, and thus friction is avoided during their passage down the casing. The casing is rectangular, and of any desired size. Its back and front are of iron plates, and the sides are of cast iron, planed true on the inside, and each has a deep recess down which one of the chains travels. This recess is planed out so that the chain fits it and fills it as closely as practicable, say with $\frac{1}{32}$ in. clearance all round. These recesses act as guides for the chains, and round them for the floats, which have a clearance all round of $\frac{1}{16}$ in., or twice the space round the chains. It is evident that the floats can thus nowhere touch the casing, which, besides, they have no tendency to do, being in perfect balance; and in work most of the links show no signs of having ever touched the guides, which is probably due to the fact that there is a considerable depth of water on each float and chain boss, and a film of water is always oozing downward under some pressure, which prevents the contact of iron and iron.

The floats are not attached directly to the links, but to brackets supported by the pin at the forward end of each link, and steadied by the hinder pin; by this arrangement the float is kept in advance of the link or pair of links to which it is connected, and is placed at a much more advantageous angle when traveling round at bottom, so that it more thoroughly exhausts the force of the descending water and escapes the resistance of the tail water. It gives, in fact, feathering without relative motion. The pulleys at bottom are loose, free to move with the chains, and the power is taken off the upper shaft and wheels into which the chains gear. Each float in turn, as it reaches the surface or the upper water, begins at once to fill *on the level*, or almost so, and continues filling till it has passed below the entering water, the water instantly on entering becoming a dwelling and acting weight. The load of water on each float carries it steadily down with the full effect due to its weight, losing nothing by friction, for there is no contact of the parts of the machine, and only 1 per cent. or under of skin friction between the water and the inside of the casing.

Though there is a space of $\frac{1}{16}$ in. all around the floats there is no leakage, as the skin friction retards the flow of a film of water of about that thickness to approximately the speed of the floats, usually 150 ft. per minute, and, in fact, if the speed of the floats were much increased there would be, so to say, a leakage upward, as they would leave the film of water behind. If there were from any cause a trivial leakage, it would only be to the float next below, and the aggregate leakage of all the loaded floats could only equal the leakage of one float descending the whole distance. The balance motor is, in fact, a machine in which force in the form of weight is made to yield a high result—probably the highest that can be obtained—by the reduction of friction and the avoidance of the loss of fall of the water-wheel and the excessive pressure, skin friction, etc., of the turbine. The principle of the balance motor is based on the proposition that water has no force but its weight, and as that is true, it follows that the machine which utilizes that weight in the most economical manner must be the best. The foregoing illustration is a diagram, but it serves to explain the chief features of the balance motor, which worked excellently at the Exhibition, and drove dynamos in the steadiest possible manner. Its cost, fixed, is also less than that of a water-wheel or a turbine. In the course of the discussion it was stated that Mr. Simon would embody the results of his test of this machine in a paper he is preparing on "Dynamometrical Tests of Power taken by Mill Machinery."—*English Mechanic.*

[Continued from SUPPLEMENT No. 556, page 8890.]

## RADII OF CURVATURE GEOMETRICALLY DETERMINED.

By Prof. C. W. MACCORD, Sc.D.

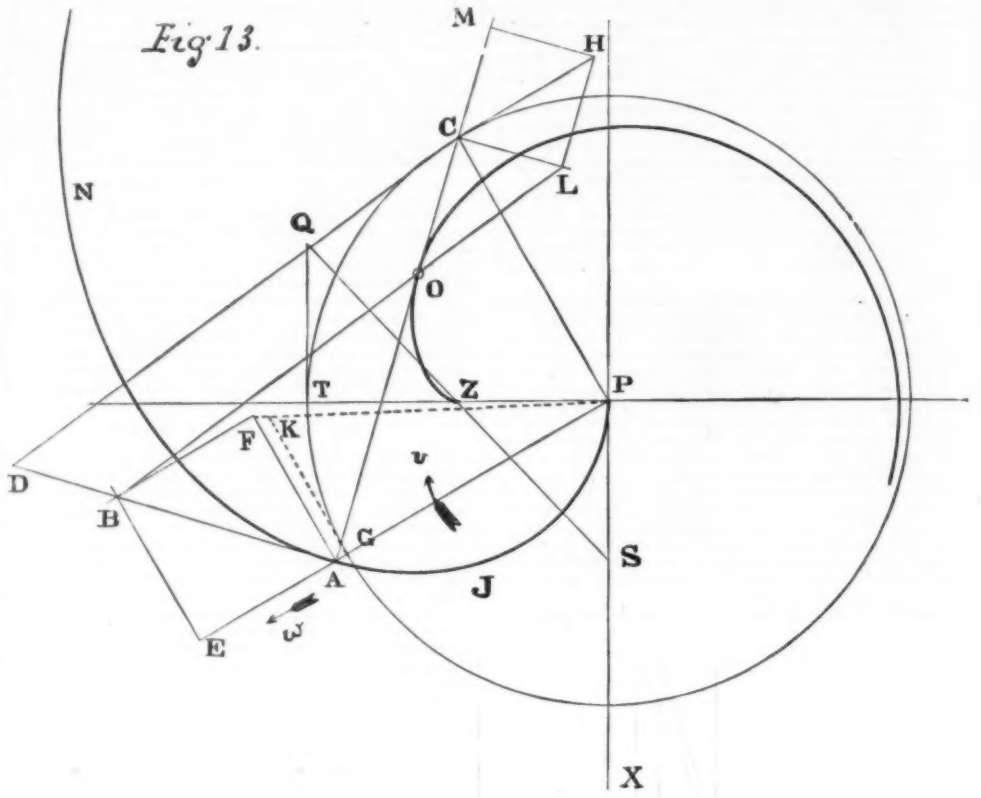
### NO. III.—THE ARCHIMEDEAN SPIRAL.

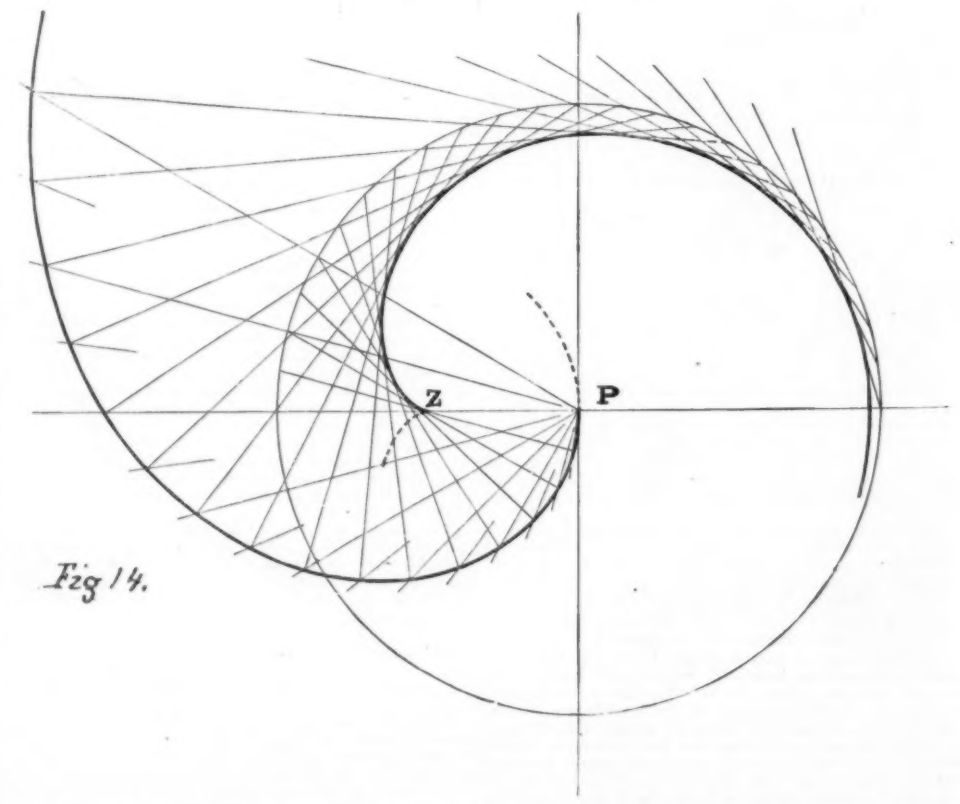
IN illustrating the specific application of the methods described in the preceding articles, we select, as the first example, the problem of determining the radius of curvature of the well known spiral of Archimedes.

This curve is traced by a point which travels uniformly along a right line, while that line itself revolves uniformly about a fixed point called the pole, through which the line passes; the rates of these two motions being independent of each other. Thus, in Fig. 13, it is easy to imagine that by appropriate mechanism a pencil at A shall be made to move with uniform speed along the rigid bar PA, as indicated by the arrow *w*, while the bar itself shall be made to revolve with uniform velocity about the fixed point P, as shown by the arrow *v*, thus describing the spiral PJN. When the rates of these two motions are known, the tangent at any point A of the curve is readily drawn by Roberval's method; thus, draw AF perpendicular to AP, and equal to the circumference of the circle of which AP is the radius; also set off along PA a distance AE equal to the *rate of expansion*, that is, the radial distance per revolution through which the pencil moves, or, in other words, the radial distance between any two consecutive coils of the spiral. These distances, it should be noted, may be laid down by any scale that may be convenient; since the direction of the diagonal AB of the completed parallelogram will be the same, whatever the actual magnitudes of its sides.

This diagonal is the required tangent, and AC, perpendicular to AB, is the normal. By repeating this operation, and drawing a number of normals, the evolute may be very easily and perfectly mapped out, as shown in Fig. 14.

Now the pencil at A may also be regarded as being carried by the extremity of a rigid bar which slides through a socket pivoted at P; and the instantaneous axis of this bar, when the pencil is at A, will be at the intersection C of the normal AC with CP drawn perpendicular to AP.




And because APC is always a right angle, the instantaneous axis must revolve about P with an angular velocity equal to that of the bar PA.

If, then, we assign any linear velocity AB to the point A in its path, we may resolve it into the components AF, AE, respectively perpendicular and parallel to AP; and drawing FP, the angle APF represents this angular velocity. Now make PG equal to PC, and draw GK, perpendicular to AP and limited by FP; then CH, perpendicular to CP and equal to GK, will represent the motion of the point C of the normal, at the instant under consideration. Resolve CH into the components, CM in the direction of the normal, and CL perpendicular to it: draw the right line LB, cutting AC in O, then OA is the radius of curvature of the spiral at A.

It will be noted that the sides of the triangles ACP,

BAE, are respectively perpendicular to each other; therefore the triangles are similar, and

$$\frac{CP}{AE} = \frac{AP}{BE}, \text{ whence } CP = \frac{AE \cdot AP}{BE};$$

but AE is constant, and so is the ratio of AP to BE, consequently CP is also constant, and the locus of the instantaneous axis is the circumference of the circle whose center is at the pole and radius the rate of expansion. All Archimedean spirals are therefore similar, in the same sense that all cycloids, involutes, and parabolas are similar; that is, if reduced to the same scale, they will become identical. It will be shown in another article that this spiral may be generated in another way, and is in fact closely related to the involute of this circular path of the instantaneous axis. But the present investigation illustrates very clearly the method of applying the geometrical principles previously explained in the determination of the radius of curvature.

And by a few additional steps, we can deduce from this construction a general formula, whose identity with that found by the usual analytical processes demonstrates the accuracy of this graphic operation.

For this purpose let

$e$ = AE = the rate of expansion.

$r$ = AP = radiant of spiral at any point A.

R = AO = radius of curvature at the same point A.

Then BE = $2\pi r$, and as above,

$$\frac{CP}{AE} = \frac{AP}{BE} \quad \therefore CP = \frac{AE \cdot AP}{BE} = \frac{e}{2\pi^2} \cdot$$

Also

$$AC = \sqrt{AP^2 + CP^2} = \sqrt{r^2 + \frac{e^2}{4\pi^2}}$$

and

$$AB = \sqrt{BE^2 + AE^2} = \sqrt{4\pi^2 r^2 + e^2} = 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}$$

Now draw CD parallel to LB, then AD = AB + CL. But

$$\frac{CL}{AE} = \frac{CH}{AB}, \text{ from sim. triang. CHL, ABE.}$$

$$\therefore CL = \frac{AE \cdot CH}{AB}.$$ But CH = AE, each being equal to the circumference of the circle through C, hence CH = $e$, and

$$CL = 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}$$

and

$$AD = 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}} + \frac{e^2}{2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}$$

Again

$$\frac{OA}{AC} = \frac{AB}{AD} \quad \therefore OA = \frac{AC \times AB}{AD} = R$$

Therefore,

$$R = \frac{\sqrt{r^2 + \frac{e^2}{4\pi^2}} \times 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}{2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}} + \frac{e^2}{2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}} =$$

$$\frac{\sqrt{r^2 + \frac{e^2}{4\pi^2}} \times 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}{\frac{4\pi^2 r^2 + 2e^2}{2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}}$$

whence

$$R = \frac{\sqrt{r^2 + \frac{e^2}{4\pi^2}} \times 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}} \times 2\pi\sqrt{r^2 + \frac{e^2}{4\pi^2}}}{4\pi^2 r^2 + 2e^2}$$

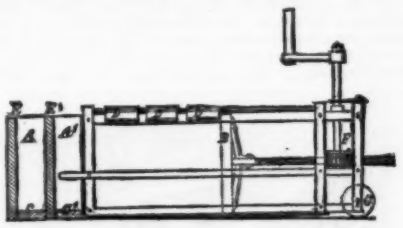
or, finally, $R = \frac{\left(r^2 + \frac{e^2}{4\pi^2}\right)^{\frac{3}{2}}}{r^2 + 2\frac{e^2}{4\pi^2}}$ = radius of curvature of spiral.

If $r = o$, this reduces to

$$R = \frac{e}{4\pi} = \text{rad. curv. at the pole.}$$

## ARTIFICIAL STONE MAKING.

THE machine shown in the accompanying engraving is taken from an illustrated description in the *Revue Industrielle* of a paper contributed by M. Hubert to the last meeting of the Societe Technique de l'Industrie du Gaz en France. It is employed by the author in the manufacture of artificial stone from gas works rubbish, such as broken clinkers, etc. It is observed in the *Revue* that the use of this class of materials in the manufacture of artificial stone is much less common than their conversion into concrete. For many purposes, however, blocks are to be preferred to concrete made in the mass; and these may be readily prepared by the aid of this machine at a cost which makes the materials employed a certain, though small, source of profit. The apparatus consists of a sheet-iron box, of any desired size, but which, in practice, may be conveniently made about 4 ft. 6 in. long, 18 in. high, and 12 in. wide. At one end is provided an endless screw arrangement, F, with a plunger, B, inside the box, which has neither top nor bottom. It lies on its side upon the ground; being supported in front by rollers, as shown. The thickness of the blocks is given by pieces of wood, C, C', C'', placed horizontally upon the bottom of the box. Opposite to them on the top, to the right and left, are sheet-iron plates, D, D', D'', of the same dimensions, which run upon iron rods, and between which are placed vertically other plates, E, E', of dimensions similar to those of the box. The last vertical dividing plate is supported in the first place by stops, for beginning work. When successive divisions, or cells, have been formed in the interior of the box, the whole is screwed up tightly by the vise, and the concrete materials are well rammed into every division. This done, the clips of the end division are removed, and the whole contents of the box are expelled by means of the screw, except the last, which serves as a closing door. It is thus the machine itself which deposits the newly made blocks upon the floor, their lack of consistency not permitting them to be handled in any way. As soon as they are all deposited, their combined resistance is such that the press itself is moved away from them by the continued action of the screw; and in this way an indefinite succession of blocks may be formed, all strongly pressed against one another. Any desired shape or moulding may be given to these blocks, which harden in a few days sufficiently to be used in structural



work, if gauged with cement. If mixed with lime, of course more time must be allowed for setting. The great advantage of this kind of masonry is the ease with which it is set, and the small quantity of mortar required. A large hospital at Vichy has been constructed of this material.

## AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BUFFALO MEETING, 1886.

AN introductory feature, which ordinarily gets but a passing notice, namely, the opening prayer, was this year made conspicuous. It fell to Bishop Coxe to perform this duty, and he did it by a compilation from the remarkable writings from an Alexandrian Jew who lived 2,000 years ago, which certainly indicated a close relation with modern thought. At its conclusion it was noticed that nearly every one present reverently joined in the Lord's Prayer that followed.

Professor Newton, of Yale College, then resigned in favor of the newly chosen President of the Association, Professor Edward A. Morse, of Salem, Mass. The usual words of welcome were spoken by the Mayor of Buffalo and the local committee; to which a suitable response was made by the President.

The fact that the firemen of the State of New York were holding a convention at the same time, as well as one or two other assemblies, served to distract public attention from the quiet proceedings of the scientific association. And yet the sessions by day time have been fairly attended; and the audience that came out at night to hear Prof. Newton's discussion of "Meteorites, Meteors, and Shooting Stars," was very large and enthusiastic.

The speaker began by reviewing the wild and crude notions that have prevailed from ancient times, down to a recent day, concerning these mysterious phenomena, some of which have been held by persons deservedly held in high esteem for their learning. This cleared the way for inquiring as to what is now held as probably true. It is agreed among men of science that the luminous tracks of meteors are in the upper part of the earth's atmosphere, from thirty to a hundred miles above the surface of the globe; that they fly with a velocity of from fifty to two hundred and fifty times that of a cannon ball; that meteors move about the sun, and not the earth, as a controlling body; that there are four comets related to four periodic star showers, coming on the dates April 20, August 10, November 14 and 27. The meteoroids causing these showers constitute a group, each individual of which moves in a path like that of its comet. Meteorites have peculiar properties distinguishing them from all terrestrial rocks, yet differ from each other in tenacity, mineral forms, and chemical composition. The most delicate search fails to find any trace of life in them. Shooting stars are solid bodies, not masses of gas. They belong to the same class with the large fire-balls and stone-producing meteors, differing only in density, size, and material. These points were demonstrated at some length, although it was conceded that the likeness of the bodies named is not admitted by all scientific men. But assuming it as established, it follows that from meteorites we may get ideas, not only as to shooting stars, but also as to comets, and possibly as to the astronomical bodies and systems of which they form a part.

Few meteoric stones weigh over 100 pounds. The most productive stone-falls furnish only a few hundred pounds each, though the meteors producing them may have weighed several tons on entering the air, and their explosion may have been heard for a hundred miles. Shooting stars weigh pounds, or even ounces, rather than tons. The smaller ones are of the size of gravel.

Meteors are not the fuel of the sun. When they fall in largest numbers on the earth, they make no difference as to its heat. Hence they cannot cause solar heat, nor do they cause the acceleration of the moon's mean motion, although they may shorten the month as measured by the day. Their effect on the weather, and also on supposed geological changes, has been greatly overestimated. The known visible meteors are not large enough nor sufficiently numerous to do the various kinds of work often ascribed to them. There are difficulties in the way of supposing meteors to have been shot out of lunar or terrestrial volcanoes. Solid bodies could not have been shot out from the hot sun. More can be said in favor of the favorite theory that meteorites came from some planet broken in pieces by an internal catastrophe; yet against it is the fact that meteors and comets are identical. It is admitted that comets do break in pieces, and the solid fragments follow in their wake. Here, then, is the true origin of the meteorites. The comets alone, of all the heavenly bodies, gives us specimens to handle and to analyze. We may expect them to yield additional secrets of their own life, and of the physics of space to the blowpipe, the microscope, the test-tube and the crucible.

In the several sections the vice-presidents made appropriate opening addresses. In section A, that of astronomy and mathematics, Prof. Gibbs discoursed on "Multiple Algebra," *i. e.*, an algebraic process in which a single letter is used to represent several quantities. Advantages are claimed for this method in its application to geometry, mechanics, astronomy, and in the calculus.

In the geological section Prof. Chamberlain spoke of the "Glacial Drift," giving an inventory of our knowledge concerning it, and describing in detail the three distinct groups into which the glacial remains of America are divided.

"The Origin of Languages and the Antiquity of Speaking Man" was the subject on which Prof. Horatio Hale, of Clinton, Ontario, spoke at the opening meeting of the section of anthropology. Protesting against the error of calling a half brutish being man, merely because he could kindle a fire and make a clumsy stone implement, he would reserve that proud name for the *speaking* race that followed, and whose first appearance was between 6,000 and 10,000 years ago. The first men spoke because they had something to say, *i. e.*, they had the cerebral faculty corresponding to the vocal organs. That faculty makes speech a necessity.

Prof. Wiley addressed section E on the "Economical Aspects of Agricultural Chemistry," showing its connection with agricultural prosperity.

Prof. H. P. Bowditch, of Boston, prefaced his address before the section of biology by vigorously protesting against the custom of requiring addresses from the vice-presidents of the sections. His inquiry, "What is Nerve Force?" made in connection with a study of the changes associated with the activity of the nerves and the results reached by the experimental observation of chemical changes, led to a conclusion favorable to the kinetic theory of nerve action.

In addressing the section of Mechanical Science and Civil Engineering, Mr. O. Chanute pointed out the laborious methods by which many inventions had been perfected, and how greatly each inventor was indebted to those who had gone before him. He strongly urged that the meetings of the Association should be made of greater value by more widely disseminating among inventors and others knowledge of what had actually been accomplished.

"Capitalists and Laborers" furnished the topic on which President Cummings, of Evanston, Ill., made the opening address before the section of Economic Science and Statistics, discussing the improvements in the condition of laborers, the causes of discontent among them, and the errors of strikes and lockouts. The time has come when employers can no longer safely refuse to confer with employes concerning grievances; and when the parties cannot thus agree, there should be arbitration. A higher standard of ethics is essential on both sides, for most of the troubles so seriously and frequently threatening the peace and order of society are due to selfish theories of morals. The great remedy is to be found in the righteous use of money.

A wide range of subjects gave the 400 or 500 scientists an opportunity, on the succeeding days, to choose the papers they most wished to hear, provided they could find out precisely when these were to be read. By the way, why could not the plan be kept up that worked so well at the Boston meeting, of having an indicator in each room showing what papers were being read at any moment in all the other sections? It had its difficulties, but saved much uneasiness and running from one room to another. We would also suggest, while in this vein of friendly criticism, that when a geological section has such really momentous questions to discuss as actually arise every year, it would vastly facilitate business could geological maps, or at least a general one of the United States, be hung up for reference, instead of leaving each speaker to sketch his outlines hurriedly and imperfectly. Facilities ought also to be provided at every meeting for lantern projections. One carefully prepared paper, at least, and probably more than one, was sacrificed at the Buffalo meeting, because there were no suitable arrangements made for illustration.

It is not easy to select specimens from the more than 300 papers that were offered to be read before the various sections, and of which 264 were actually accepted! The attendance was remarkably good in all the rooms; and the close adherence to system and time allotted, and also the fact that fewer general sessions were held than usual, helped those having matters in charge to get over as much ground as possible.

Mention should be made of the delightful social receptions and excursions planned for the scientists, by which the fatigue of steady work was relieved, and an opportunity afforded for the savants to get acquainted with each other. The excursions to Chautauqua, Grand Island, and the Falls of Niagara, as well as several botanical and geological trips, were all enjoyable and highly instructive.

## THE PARISIAN FIRE DEPARTMENT.

THE fire brigade of Paris is not organized on as extensive a scale as Captain Shaw's, and, in consequence, several fires which lately occurred have not been extinguished as quickly as was desirable. It was also found that the people were not disposed to become amateur firemen. The Prefect of Police has therefore advised the various commissaries that the ordinance which dates from December 11, 1852, can still be put in force. According to it, all masons, carpenters, roofers, plumbers, and other workmen are bound, whenever requisition is made on them, to proceed forthwith to the place on fire and to bring their tools and ladders. Horses are also to be supplied on demand to the owners. Chandlers and grocers are under obligation to supply the torches which may be necessary in order to give light during the operations. The requisitions can be made by the commissary of police or the officer commanding the firemen on the occasion. It is not supposed that the work is to be gratuitous, for the labor and goods will be paid for on production of a certificate duly signed. But any person who will not comply with the requisition can be prosecuted. The Paris houses fortunately take a long time to burn, otherwise there would be little hope for them with so improvised a service.

## HOW TO MAKE PRINTING PLATES OR ENGRAVINGS BY ETCHING.—GILLOTAGE.

SEVERAL of our readers having asked us to give them some information in regard to the production of engravings by the Gillot process, we hasten to comply with the request, as the subject is one of general interest. We cannot do better than copy the chief passages from a report presented to the Societe d'Encouragement "Upon Messrs. Gillot & Son's Processes of Typographical Engraving," by Mr. Davanne, whose competency is well known to all. These processes have become thoroughly practical, and are now known under the name of gillotage.

In order to obtain an engraving in relief by gillotage, there are different phases, which comprise (1) the making of the drawing (or, most generally, a reproduction thereof by photography), its impression upon the surface of zinc, and the removal, through acid, of all the parts that must be depressed in order to leave the image in relief.

In reviewing these successive operations we shall begin with the last, which is the chief part of the process.

Upon a zinc plate 3 mm. ($\frac{1}{8}$ in.) in thickness, which has been previously planed, and the surface of which has been properly polished, we obtain the image to be engraved by means of some such substance as ink, bitumen, or varnish. This image is produced directly, or by photography or transfer. The plate is then covered on the back, edges, and the broad blank spaces with some isolating substance that shall prevent the acid from attacking such parts to no purpose. The margins and spaces thus prepared will serve during the course of the work to support the inking roller and prevent it from entering the hollows that it must not reach. These parts will afterward be routed out.

The plate is now ready for biting-in. An examination of the difficulties to be surmounted in order to obtain a good engraving will aid us to better understand the work in general. It is necessary to prevent the acid, through its saturation with the zinc, and the density thereupon resulting, from settling in the state of inactive nitrate of zinc in the depressions, leaving the action of the free acid to be exerted toward the surface and to undermine the lines of the drawing and destroy their solidity. These depressions must be so deep as not to become quickly clogged up by the printing ink.

In order to obtain a proper resistance and firmness in the lines, it is necessary to prevent the acid from making the base that supports them too thin, and to strengthen the base by giving the depression the form of a V, and the base itself the form of an A. The depth must be great enough in the broad blanks to prevent the roller from sinking (although there is no danger of this when the lines are close together), and thus soiling them. A useless depth between very thin sides might weaken them; but in the process employed the attack by the acid continues only in proportion to the width of the spaces to be excavated.

These results are obtained as follows: The prepared plate bearing the design is inked with a thick ink containing a little wax, and is placed in a trough with acidulated water, which slightly attacks the metal.

The trough is mounted so as to rock, and is kept in motion by a lever actuated by a steam motor. The water moves to and fro over the entire surface, and keeps continually washing the parts that are not protected against its action. No local saturation therefore occurs, and the continuously renewed liquid attacks the bottom as well as the sides of the hollow. The sides would soon be rendered too thin were the biting-in too long continued, and for this reason the first attack is made with great care. It is upon this that depends the sharpness of the proof. The acid used is nitric, so dilute that it is scarcely perceptible to the taste, and in the proportion of about one and a half ounce to a quart of water. The acidity is kept up by a small quantity of acid of 36°, that falls drop by drop from a bottle provided with a cock. After about a quarter of a hour, the plate is taken out.

The depressions are as yet scarcely perceptible to the touch, and on being continued, the vertical sides must be protected and only the bottom hollowed out. To this intent, the plate is sponged and dried and placed upon a table, which is heated by steam from the motor. The thick ink that covers the lines liquefies slightly, and overflows and descends along the sides of the depressions to form a protective coating. The plate, having been cooled, is inked anew and dusted over with resin in impalpable powder, which adheres solely to the inked parts, whatever excess there is being removed by the subsequent bath. The plate is then put into the trough again with a little stronger acid, and these operations are repeated eight, ten, or twelve times. On proceeding thus, the ink that descends along the sides of the depressions encroaches more and more upon the bottom, and, if the lines are very close together, the two streams will join each other at the base so much the quicker in proportion as the space is narrower.

It is easy to follow the course of the etching and the operation of the ink. In measure as the latter completely fills the depressions the fine parts of the design become covered, and, at the end of the operation, the entire surface, save where there are broad lights, is seen to be black.

At every new biting-in, the acidity of the bath is increased, and, when the broad parts alone remain exposed to the attack, acid of 6° B. may be used. In this state, the zinc plate, taken from the bath and washed and dried, is treated with benzine, and then with potash, in order to remove all fatty matter. It may then be seen that the sides of the hollows do not exhibit a regular sloping surface, but a series of ridges corresponding to the series of bitings-in. As these might take the ink and affect the purity of the lights and shades, it is necessary to remove them by an operation analogous to the first, but carried on quickly in an opposite direction. With this intent, the plate, well cleaned and heated upon the iron table, is inked while hot with a composition formed of two parts printing ink and one part each of resin and beeswax. This ink, which can be used hot only, descends along the sides of the depressions, and when it has got half way to the bottom the plate is cooled, and the inking is renewed so as to well cover the entire surface.

Then the plate is heated anew in order to glaze the ink and to leave no point unprotected. Then it is put into the trough with acid of 5° B., which quickly eats off the series of ridges and renders the depressions deeper. The entire operation is repeated, and the inking is so performed that the upper ridges may be removed. Finally, a slight biting-in effects the removal of every trace of ridges.

The etching is then finished, and it only remains to rout out the superfluous parts, and trim the plate in to shape with a saw, and mount it upon a block of wood of the proper thickness.

These operations are rapidly carried on in a very large room (Fig. 1), which is well aerated in order to eliminate the nitrous gases resulting from the etching of the zinc. The troughs are actuated by two engines, one a gas motor of four horse power, and the other a steam one of six horse power. These engines also run the sawing and routing tools, as well as a Gramme machine for producing an electric light when necessary.

It takes about four hours to etch a plate, and the operation is so much the easier in proportion as the design is more complicated. Thus, the etching of a line, a dot, or a page of music is more difficult than that of a labored drawing. The price, then, can be calculated,

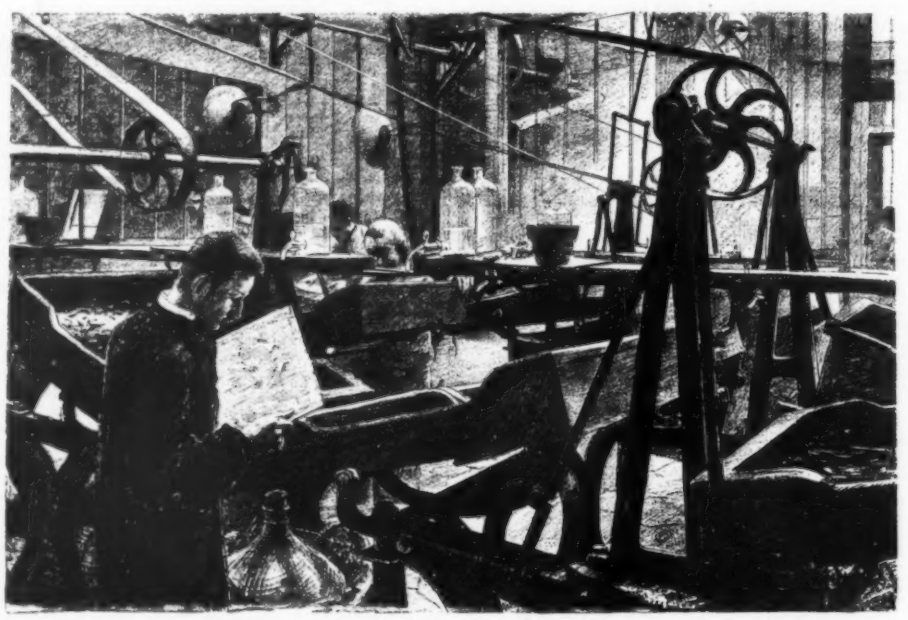


FIG. 1.—THE BITING-IN ROOM AT THE GILLOT ESTABLISHMENT.

not according to the apparent importance, but to the *pro rata* of surface.

It must not be believed that in practice these operations can be conducted without extreme care. A want of attention, unsuitable ink, or a too high or low temperature may lead to the loss or poor execution of the piece. It is often objected that the lines in this style of plates have not the boldness of those produced by the graver. It is not for us to answer the question whether this is a merit or a defect; artists generally endeavor to employ paper with an irregular and granular surface, and which is far from giving such boldness, and he perhaps would be poorly appreciated who should present upon glazed paper a drawing made with the pen and resembling a picture made with the graver. It is the artist's business to produce the work such as he desires the gilloteur to render it.

We have stated that the starting point of producing a gillotype is the obtaining of an image on the surface of a zinc plate with a thick ink or a varnish. There are several methods of reaching this result. The artist may himself make a reversed drawing upon the zinc; but in this case he is doing something contrary to his habits, and he is under restraint, and the same is the case if he is asked to use autographic paper or ink. Gillot the elder formerly always used a copper plate or lithographic proof pulled with transfer ink, and this he transferred to the metal to be etched.

Under such circumstances, the services rendered were limited to works already in print, and free-hand drawings could not be used. On another hand, as the reproduction was of the same size as the original, it rarely fitted in the text, and such a conversion of an engraving or lithograph into a typographic plate could not have that interest that it now has, being given the different processes that render the modification of page sizes easy. Besides, a transfer is rarely effected without making the lines coarse.

At present, all such conditions are changed through the intervention of photography. The objective gives an exact reproduction of the original in any proportions desired. This original, instead of being altered or destroyed, as formerly often happened, is now hardly touched. It is not always necessary to bring it to the photo-engraver's, for the camera goes to get it, and reproduce it from among public and private collections, and the negative obtained will give, through the action of light alone upon a thin coat of bitumen previously spread over the zinc, an inkable image ready for biting-in.

The photographic studio, then, has become an indispensable part of a gillotage establishment. It is in it that begins the work, the reproduction of a design that must be as perfect as possible; so Mr. Gillot has bestowed particular care upon this part of the plant, for which he has had special models constructed.

Three cameras, supported by cast-iron standards, are arranged in a well lighted room (Fig. 2). The negative is obtained by the wet collodion process, and is detached from the glass by means of a solution of India rubber in benzine, thus permitting of its being reversed and etched in that state, and of an image being obtained in the true direction when printed. The photographic operations take less than an hour for their performance, when the particular negative, having been reversed and affixed to glass with a little gum-water, is ready to be applied to the zinc.

The zinc plate, well cleaned upon one surface, is first covered with a thin and regular coat of a solution of 4 parts of bitumen in 100 of benzine. This is allowed to dry, and the negative is applied. The whole is placed in a plate-frame, and fastened with a thumb-screw in order to secure that perfect contact which alone can produce a sharp image. An exposure is

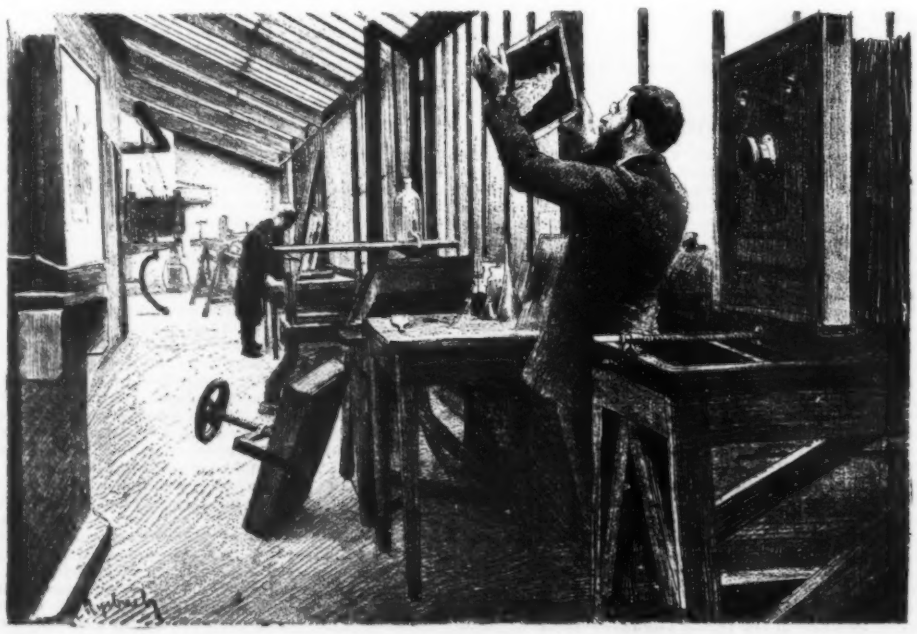


FIG. 2.—GILLOT'S PHOTOGRAPHIC STUDIO.

then made for a period that varies according to the brightness of the light, generally for one or two hours. When it is actually necessary, the electric light may be substituted for the solar, but on condition that the luminous source be very near the frame; and in such a case, Mr. Gillot makes use of a frame provided with two glasses, with a circulation of water between them, in order to prevent heating. After sufficient exposure, the plate is washed in spirits of turpentine, which dissolves the bitumen in all the parts in which the light has not rendered it insoluble. The action of the turpentine is arrested by forcing a jet of water under pressure against the surface, and then the plate is sponged and dried, and in this way there is obtained a very sharp image, ready for the gillotage process.

Every design, then, can be converted into a typographical engraving on condition that the exigencies of photography and typography be taken into consideration. The troubles connected with photography relate especially to the action of the various colors of the pattern upon the sensitive coating. But such difficulties are every day being diminished by the progress that is being made in this direction. The typographical troubles are connected with the paper, machines, and ink, which latter does not always produce the same effect as it would with an engraved plate. In fact, it is impossible to obtain, with opaque inks, those degraded mezzotints that are exhibited by a wash. Lithographic ink is of a uniform black, without transparency. It is not, then, through the ink's varying thickness, but solely through the proportion of the distances between the lights and shades, that our eye appreciates the degradation of tints; and, under such circumstances, the reproduction of a wash will give merely a uniform, black impression.

If such difficulties are connected with the original, they must be surmounted by giving the plate a grain; but this is a complication, and it is preferable that such work shall have been done upon the pattern itself in advance. As long ago as 1877, Mr. Gillot asked artists to make their drawings in such a way that they would present the effect of an engraving upon wood. The designer, after lightly sketching his subject upon laid paper, passed over its surface a little wheel, which, through the crossing of the lines, produced a series of indentations, resembling the incisions made in wood by the tool of the engraver. Then, upon the paper thus striated, he drew his picture with a crayon. As the black only took upon the striæ, the effect produced was that of an engraving, which, being photographed and reproduced by gillotage, gave the plate demanded.

Later on, in order to render certain drawings upon colored or antique paper with more harmony, Mr. Gillot found it advantageous to give the entire ground a slight tint, and this he obtained by a general striation, which the light modified through the negative. This process has especially been applied in the reproduction of prints in the Louvre.

Finely tinted and striated papers have now come into more general use. These are furnished to the artist, and he can use the sheets for his drawing in any way that he likes—impasting certain parts with intense black, scratching out others for bright lights, and making use at his convenience of crayon, pencil, or eraser, but only very rarely obscuring the striæ, which always show through, except in absolute blacks. The original drawing is thus in the condition required by typography. In order to obtain greater sharpness, the pattern is almost always copied in reduced size in the camera; but such reduction must not be too great, since, although photography can condense lines almost to infinity, it is necessary to stop before what might be called the relative imperfection of typographical printing, which requires sufficient space between dots and lines to prevent an immediate filling in through the rapid and somewhat faulty inking on the process in general use, and to which it is necessary to conform the work ordered, by not giving it an exaggerated sharpness.

It is likewise due to the method of bringing into relief through acids that typography is enabled to cope successfully with polychromatic printing. The artist first makes his drawing, and this is then photographed and etched in relief, and a proof sent to the draughtsman to receive the color. After the proof has been colored, an estimate is made of the number of plates that will be necessary in order to render the effect, and upon each of these plates, through reserves and counter drawings, only that portion is bitten-in that relates to the color that is to be produced. The biting-in is done after the surface has been given what is called a resinous grain, which is varied, as in aqua-tint, with the difference, however, that the more the biting-in is repeated, the lighter become the tints, which is just the reverse of what obtains in copper-plate engraving. The plates thus prepared, with accurate junction marks, are sent to the printer.

The engravings that accompany this article were made especially for *La Nature* by gillotage. The drawings were made with a pen upon grooved paper by Mr. Myrbach, and the photographing and transfer to zinc were performed at Mr. Gillot's establishment.—*La Nature.*

## APPARATUS FOR MANUFACTURING CARBURETED AIR GAS.

CARBURETED air gas, which is now much employed by the owners of factories, country-seats, etc., is, as well known, manufactured by forcing air under pressure through a very volatile hydrocarburet, such as naphtha, petroleum, benzine, etc. The air becomes impregnated with the vapor, that is, becomes carbureted, and instantaneously converted into a gas whose flame possesses a greater illuminating power than that afforded by common coal gas.

Many methods have already been employed for producing the action necessary for forcing the air in sufficient quantity to supply the conduits, but we believe that none has hitherto given entire satisfaction. These methods, as a general thing, consist in the use of a heavy bell or of a counterpoised blower, which forces air into the carbureter, and the least drawback of which is that it requires frequent lifting. Moreover, such apparatus possess another serious drawback, and that is that the depression in temperature produced by volatilization is in nowise compensated for; so that, after an operation of an hour or two, the flame lowers to an abnormal degree.

Such inconveniences are suppressed in the apparatus manufactured by the Carbureted Air Gas Society, which we illustrate herewith. This apparatus consists of the five following parts: (1) Of a gas-motor, A, which actuates the air-pump, *a*, that furnishes the air under pressure; (2) of a reservoir, B, which stores up the air furnished by the pump; (3) of a carbureter, consisting of a receiver, $C_1$, into which plunges a closed vessel, $C_2$, containing a small quantity of gasoline, and which is traversed by the air under pressure coming from B, of a gasoline reservoir, $C_3$, and of a gasometer, $C_4$; (4) of a heater, D, that keeps up a uniform temperature in the water of the receiver, $C_1$; and (5) of a Wiessnegg temperature regulator, E.

*The Motor and Air-Pump.*—The gas engine, A, actuates the double-acting air pump, *a*, each end plate of which is provided with a force and a suction valve. The air is sucked in from the exterior and forced into the bent pipe, *b''*, which is connected with the pipe, *b'*, that leads the air into the reservoir, B, through the pipe, *b*.

*The Air Reservoir.*—The air, entering through the pipe, *b*, lifts the receiver of the reservoir, B (which latter is filled with water), and causes it to rise until it abuts against the cross bar, *d*. The air contained in the receiver makes its exit through the pipe, *c*, which leads it to the carbureter. In its ascensional motion, the receiver is guided by rods, *d'*, that slide along the uprights, and by the central tube, *e*, which surrounds the stationary rod, *d''*.

The object of the valve, *s*, is to allow of the escape of the excess of air that enters when the receiver has reached its highest position.

*The Carbureter.*—This consists of a large iron plate cylinder, $C^1$, surmounted by another and smaller one, $C_4$, representing the gas reservoir. When the air comes through the pipe, *c*, from the reservoir, B, it enters a compartment, J', which dips into the gasoline. This compartment, whose periphery is of iron plate, is provided with two disks, KK', containing very small apertures. The air entering under pressure, through the pipe, *c*, becomes carbureted in contact with the liquid, which it causes to bubble, and, traversing the perforated disks, K, K', K'', as well as the apertures, *z*, in the lower part of the compartment, J', flows in the form of gas into the receiver, $C_4$, through the pipe, M.

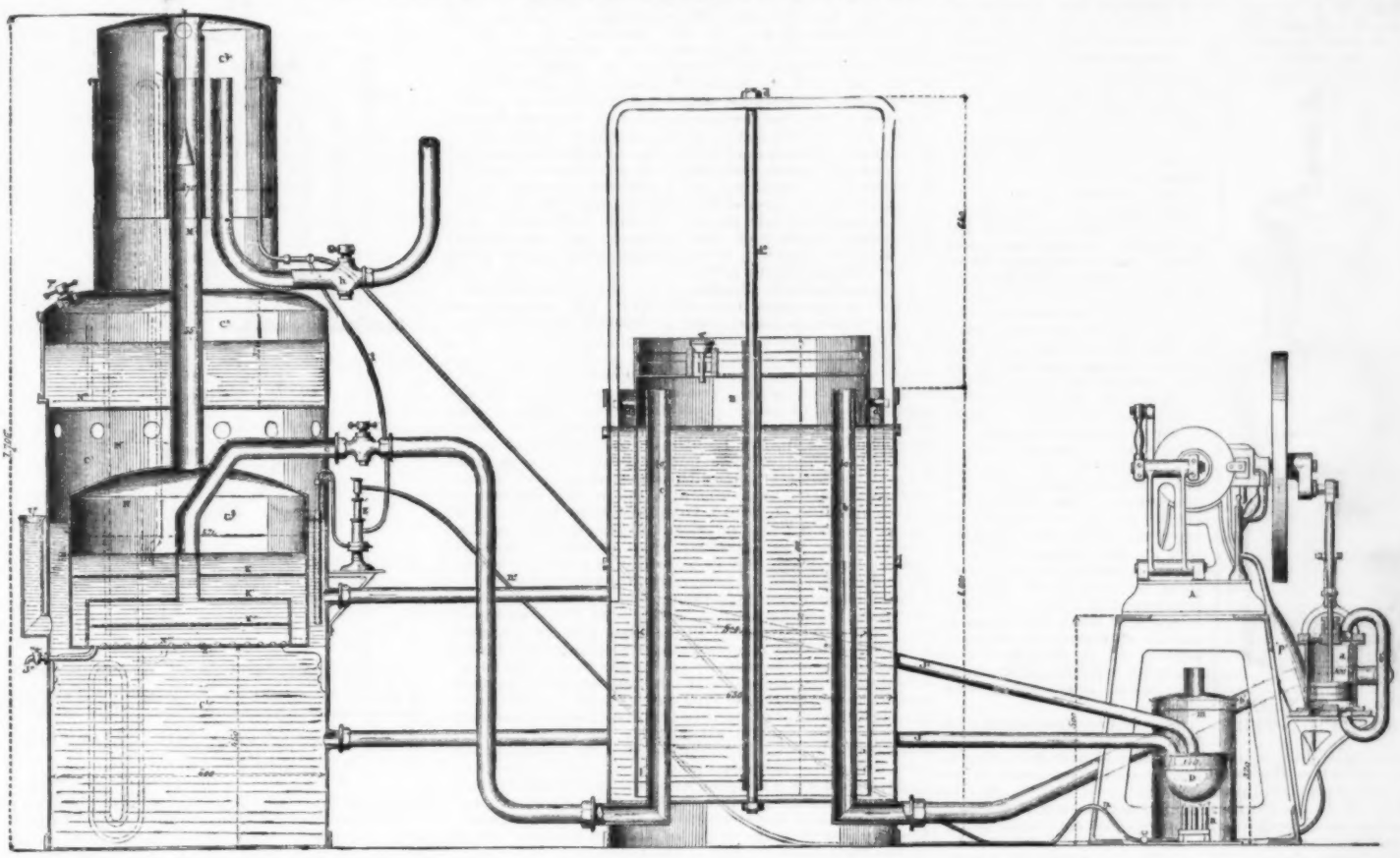
When the level of the liquid lowers in the carbureter, the insufficiently carbureted air no longer produces anything but a gas of feeble illuminating power. It is therefore indispensable to have the level of the liquid constant. With this intent, the upper part of the carbureter is provided with a reservoir, $C_2$, which is filled with gasoline through the aperture, P. The reservoir, $C^2$, and the receiver, $C^2$, are connected by a curved pipe, N, which operates as follows: At the moment the level of the liquid falls beneath the line, *xx*, the orifice, *q*, is open, and the carbureted air under pressure enters the pipe through the orifice, *N'*, and reaches the reservoir, $C_2$, the direction followed being shown by the arrows. A pressure then occurs upon the gasoline in the reservoir, and the liquid is forced into the pipe, *N*, through the orifice, *N''*, and enters the receiver, $C^2$, through the aperture, *N'''*. As soon as the liquid reaches the level, *xx*, again, the orifice is closed, and, as the gas under pressure can no longer pass, the supply at once ceases.

When it becomes necessary to empty the receiver, $C^2$, use is made of a purge-cock, J'', mounted with such intent upon the carbureter.

The elbowed pipe, *g*, serves for the introduction of water into $C^2$.

This pipe at the same time shows the level of the water in the receiver, and, when a thermometer is inserted into it, permits of ascertaining the temperature of the water.

*The Heater.*—From the evaporation of the gasoline in the receiver, $C^2$, there results in the latter a depression of temperature, which just so much diminishes the illuminating power of the gas produced. In order to obviate this trouble, it is necessary to heat the water in the reservoir, $C^1$. With this intent, the heater, D, consisting of a hemispherical vessel, is provided with two pipes, J and J', which communicate with $C^1$. The



APPARATUS FOR MANUFACTURING CARBURETED AIR GAS.

heater, which is placed in the interior of an iron plate cylinder, *m*, is in contact with the flames of burners, *n*.

The hot water flows to the carbureter through the pipe, J', while the pipe, J, leads cold water to the heater. A constant circulation is thus set up. The burners, *n*, receive gas from the reservoir, C', through the pipes, *n'* and *n''*, which are connected by the regulator, E.

*The Temperature Regulator.*—The object of this is to regulate the entrance of the gas into the burners, *n*, so that when the water in the receiver, C', has reached its normal temperature of 14° or 15°, the burners shall go out of themselves. As soon as the temperature drops in C', the regulator allows the gas to pass again, and the burners are relighted by a small burner with a low flame placed near them.

This regulator is provided with a copper tube, O, which is filled with glycerine, and enters the water in C'.

From this new arrangement of the various parts there results an absolutely automatic apparatus. In fact, the gas engine, through the intermedium of the air pump, furnishes the air that is converted into gas. A portion of the gas formed, being sent to the motor through the pipe, *p*, and pocket, P', serves to actuate the engine; so that the latter produces gas in the carbureter, and the carbureter actuates the motor through the intermedium of this same gas.

Carbureted air gas gives an agreeable, white light, which does not fatigue the eyes. It is perfectly pure, being free from those sulphurous and ammoniacal products that render coal gas so injurious to the respiratory organs, and that spoil paintings, gildings, etc.—*Annales Industrielles.*

## THE POSOMETRICAL DROP-COUNTER.

ALL those who have had to make chemical analyses or prepare pharmaceutical products well know how difficult it is to accurately measure the number of drops of a liquid that it is desired to add to another one, in small quantity, in a precise and definite proportion. Mr. Alfred Jannin, a pharmacist of Chalon-sur-Saone, has devised a very practical drop-counting bottle, which we think is deserving of a description.

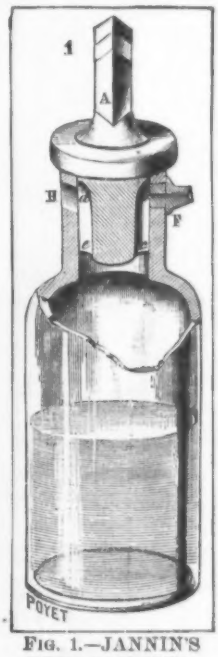



FIG. 1.—JANNIN'S DROP-COUNTER.

Fig. 1 represents the bottle closed, its upper part being shown in section.

The stopper, A, has in its lower part two opposite grooves, *bc* and *de*, which are of equal dimensions, and which widen slightly from top to bottom. One of these communicates with an aperture, F, in the neck of the bottle, that is provided with a metallic nozzle, and the other with an aperture, H, in the neck, that should be at least 4 mm. in diameter, in order to make the operation of the apparatus regular.

In order to use the bottle, the grooves in the stopper must be brought opposite the apertures in the neck; the bottle must be inverted in order to expel such air bubbles as may remain inclosed in the groove, *bc*, and must then be held in a slanting position (Fig. 2), and so that the nozzle shall be beneath and its extremity, *op*, be horizontal. If the drop does not make its appearance at once, the bottle must be gently shaken.

The liquid, finding an exit through the aperture in the nozzle, falls drop by drop by virtue of its own weight, and air enters the bottle through the aperture, H, in measure as the dropping proceeds.

If we turn the stopper (which may be compared to a quarter-circle cock-plug), the grooves no longer being in communication with the apertures, the bottle will be hermetically closed. We would call attention to the form of the nozzle, which contains an aperture 6 mm. in length, that communicates with a very divergent cone. It is this latter that constitutes the principal part of the instrument, since it has a great influence upon the regularity with which the liquid flows.

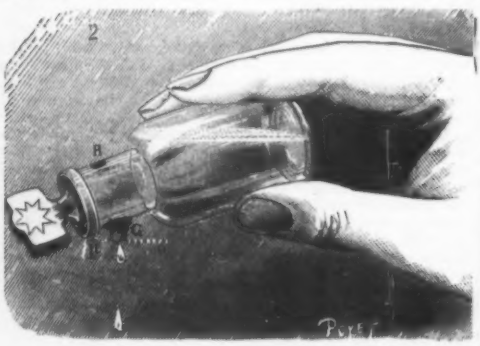



FIG. 2.—METHOD OF USING THE DROP-COUNTER.

As the entire conical surface is immediately wet, every drop has exactly the same weight as the first, and the drops detach themselves better, and never run over the external edges, as they do in most of the drop-counters that have hitherto been constructed.

The nozzle may be changed, as there are four different models of it that answer to the various requirements of therapeutical preparations. There is one for distilled water and aqueous solutions, one for Fowler's solution, one for laudanum, and one for tinctures or alcoholic preparations. Mr. Jannin has had to greatly modify the nozzle.

The cone, which may be called a cone of adherence, must vary in diameter in wide proportions. While the extremity of the cone of the nozzle must have a diameter of 3·2 mm. to give drops of distilled water of the weight of 5 centigrammes, it must have one of 3·7 mm. for Fowler's solution, one of 4·1 mm. for laudanum, and one of 7·9 for tinctures.

As the rate of flow is proportional to the internal diameter of the tube through which the liquid comes, the inventor has had to make the aperture 6 mm. in diameter, so as to give nearly sixty drops per minute. Under such circumstances, the drops come neither slowly nor rapidly, and the eye can follow and easily count them.

This process of dropping is very accurate, almost mathematically so, for the weight of the drops does not vary by one five-hundredth. Mr. Jannin calls his bottle a *posometrical* (size-measuring) *drop-counter.*—*La Nature.*

## NEW APPARATUS FOR THE ESTIMATION OF CARBONIC ACID IN THE AIR.

By THOMAS C. VAN NUYS.

FROM results of the estimation of carbonic acid in the air since Pettenkoffer* published his method, it is evident that either the amount of carbonic acid in the air varies greatly at different times or the methods employed are defective. Later investigations tend to prove that the methods are not reliable, the estimations being too high. Truchot's† maximum quantity found in forty-nine estimations made during fine weather was 4·2 volumes in 10,000 volumes of air, and where the ground was covered with snow his maximum quantity was 8·7 volumes. H. and A. Schlaginweit‡ found from 3·2 to 5·8 volumes in 10,000 volumes of air, according to altitude. Mene§ found 7 volumes in 10,000 volumes of air. On the contrary, G. F. Armstrong‖ claims that the quantity of carbonic acid in the air does not exceed 3·5 volumes in 10,000 volumes of the air, and J. Reiset's¶ maximum quantity in ninety-one estimations was 3·415 volumes in 10,000 volumes of air, the average number of volumes being 2·978. Generally considered, the methods for the estimation of carbonic acid in the air, whether by passing air through tubes containing a solution of barium hydrate or by shaking up a definite quantity of a standardized solution of barium hydrate with a measured quantity of air, do not provide sufficiently for preventing contact of the external air containing $CO_2$ with the $Ba(OH)_2$ when titrated with oxalic acid or when filtered and washed.

By the apparatus illustrated by the figure, it is intended to overcome this difficulty. The capacity of the apparatus, A, ascertained by having determined its weight when empty and dry, and its weight when filled with distilled water at 4° C., is 6,177 c. c. The diameter of the mouth, *a*, of the apparatus is from 22·5 to 25 mm. The inside diameter of the end, *b*, of the apparatus is 65 mm. This drawn out, part of the apparatus is provided with a glass stop-cock, *c*. The stopper, *d*, fits in the mouth of the apparatus by a ground surface so as to be perfectly air-tight. A hole 4·5 mm. in diameter passes through the stopper, closed above by the rubber tube, and below the stopper is drawn out so as to form a tube which is bent and is connected to a piece of glass tubing by means of a rubber tube. The attached piece of tubing is bent upward and drawn out so its orifice is 4 mm. in transverse diameter and 1·5 mm. perpendicular diameter.

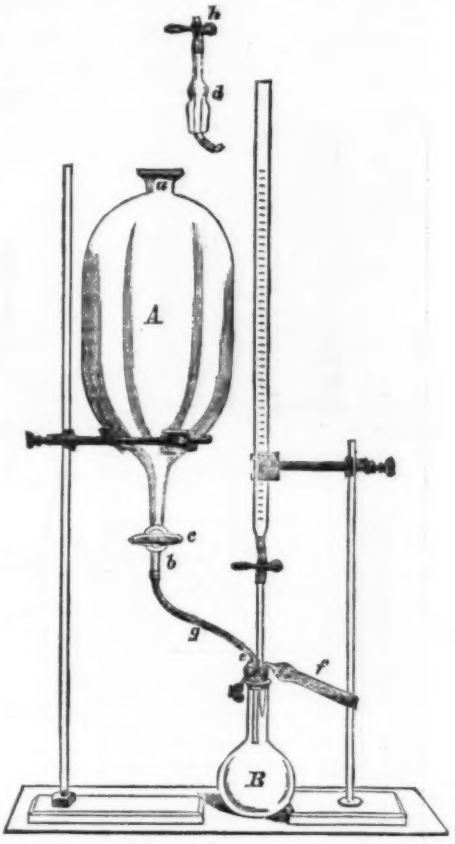
When the stopper is in place, with a small quantity of grease it can be readily turned with the thumb and one finger. The capacity of the flask, B, is 400 c. c., and it is provided with a rubber stopper having three holes. Through one of these holes passes the bent glass tube, *e*, which is connected with the apparatus; through another hole the tip or dropper of the burette; and through the third hole the bent end of the chlor-calcium tube, *f*. This tube is filled with pieces of pumice saturated with a strong solution of natr. hydrate. In estimating the carbonic acid in the air with this apparatus, I use a solution of oxalic acid standardized according to Pettenkoffer,** and a solution of barium hyd. of one-half the strength of that of Pettenkoffer, thereby avoiding an excess of barium oxalate, which makes the disappearance of the red color of the rosolic acid more obscure. 2·8636 grammes pure oxalic acid which has neither effloresced nor deliquesced are dissolved in 1,000 c. c distilled water. 1 c. c of this solution has the same saturating power as 1 milligramme $CO_2$. About 3·5 grammes pure barium hydr. and 0·5 gramme barium chlor. are dissolved in 1,000 c. c. water. If the solution is not clear, it should be filtered. The solution should be kept in an aspirator bottle, the stopper of which is connected with a large chlor-calcium tube having its end bent, and the tube filled with pieces of pumice saturated with a strong solution of natr. hydrate. In titrating the Ba hydr. solution with the solution of oxalic acid, contact with the external air is avoided by employing Pettenkoffer's †† method in filling a pipette. The flask, B, may be employed in this titration. Two or three drops of an alcohol solution of rosolic acid are introduced into it, the rubber tube, *g*, is removed from the end of the apparatus and is connected with a wash-bottle containing a solution of natr. hydrate, and a U shaped tube containing soda-lime. The end of the chlor-calcium tube, *f*, is connected with an aspirator bottle filled with water, and air is drawn through the apparatus until the flask is filled with air free of $CO_2$. The end of the rubber tube, *g*, is taken between the thumb and finger and carefully disconnected, and placed over the tip or dropper of a 50 c. c. pipette containing the Ba solution, and when the solution has run into the flask, the end of the tube is removed from the pipette, with the precaution that no outside air enter the tube. It is fitted over the mouth-piece of a wash-bottle filled with water.* About 100 c. c. water is passed into the flask through the rubber tube, when it is secured by the pinch-cock. The oxalic acid solution is added until the red color disappears. Titrations should be repeated until an agreement is reached. As the oxalic acid solution is liable to change, titrations should be made every two or three days to avoid the uncertainty of results owing to decomposition of the acid in solution.

The stopper, *d*, is prepared for use by filling the canal passing through its entire length with water, as a pipette is filled when the rubber tube is secured by the pinch-cock. The ground surface of the stopper is then rubbed with grease.

The inside surface of the apparatus, A, is dried, either by washing with absolute alcohol and ether, and let remain open in a warm place until dry, or by attaching the tube, *b*, to a foot bellows by means of a rubber tube, and pumping air into it until dry. In this way the apparatus is filled with the air, the $CO_2$ of which it is intended to estimate.

The flask, B, is dried, and into it are put two or three drops of an alcohol solution of rosolic acid. Air is introduced into it, having its carbonic acid separated as before, when the rubber tube, *g*, is secured by the pinch-cock.

The apparatus having been filled with the air, the carbonic acid of which it is intended to estimate, a thermometer is suspended in the apparatus and let remain thirty minutes, so the temperature may become constant, when the temperature and barometric pressure are noted. Fifty c. c. of the barium solution are




NEW APPARATUS FOR ESTIMATING CARBONIC ACID.

introduced into the apparatus, A, the glass stop-cock having been closed. The stopper is put in place and secured by means of a rubber band. The apparatus, A, is turned on its side, placed on a table, and by frequent turning the inside surface is kept wet with the solution, and after the lapse of two hours all of the carbonic acid will have been absorbed. The lower end, of the apparatus is raised a short distance from the table, and the tube, *b*, is filled with water from the glass stop-cock to the end. The apparatus is returned to its place on the stand, the water remains in the tube, and the end of the rubber tube, *g*, which is attached to the glass tube, *e*, is filled with water from the part of tube secured by the pinch-cock to the end and fitted over the tube, *b*, carefully excluding any air. The pinch-cock is removed to its place, as shown in the figure, and the glass stop-cock is carefully turned. If the air in the apparatus is under less pressure than the outside air, bubbles will pass through the barium solution into the apparatus, in which case the stop-cock should be turned so that the air may pass into the apparatus slowly, and all the carbonic acid of the air be absorbed as it comes in contact with the natr. hydrate solution in the chlor-calcium tube. In a short time all of the barium hydrate solution will have passed into the flask. The rubber band or cord which secured the stopper in place is removed. An inspirator bottle containing water is placed one meter above the apparatus, and by means of a rubber tube 6 mm. internal diameter, connection is made between it and the rubber tube, *h*, attached to the stopper and secured by the pinch-cock. The rubber tubing making this connection should be filled with water to the exclusion of any air. As the pinch-cock is removed from the rubber tube at the stopper, the water will flow into the apparatus and is thrown against its surface. By means of the thumb and finger the stopper is turned slowly, so every part of the surface is washed. If the rubber tube should become twisted, it can be prevented from turning with the other hand, provided the tube does not fit too tight. By careful washing, not more than

* Sitzungsberichte der k. bayerischen Acad. d. Wissenschaft, 1860, 291.

† Ann. agronomiques, 1877, 69.

‡ Pogg. Annalen 76, 462.

§ Ann. de la societe des sciences industrielles de Lyon, Nos. 1-6, in Rep. Chim. App. iv., 473.

‖ Proceedings Royal Society, 30, 343.

¶ Comptes Rendus, 90, 1,144.

** Annalen der Chemie, Suppl. Band 2, 25.

†† Mohr's Titrirmethode, Vierte Aufl., 140.

* Every case in which water is used which will subsequently come in contact with the Ba solution, distilled water having been boiled is employed.

250 c. c. water will be required, which was determined by introducing 2 c. c. strong hydrochloric acid and 40 c. c. water, and washing until the acid disappears from the wash-water. The rubber tube, *g*, is secured by the pinch-cock, and the end is removed from the tube, *b*. The bent tube, *e*, is drawn up so its end comes within 3 cm. of the stopper, and the long tip of the burette is carefully pushed further into the flask, and the barium hydrate is titrated by letting 20·5 c. c. of the oxalic acid solution run in from the burette at once, and after gently shaking, one or two drops are added, and so on until the red color disappears. The data of one estimation are here given:

50 c. c. of the barium hydr.=24·5 c. c. of the oxalic acid sol. Temperature, 4° C. Barometric pressure, 743·5 mm.

| | |
|---|---|
| Capacity of apparatus..... | 6,177 c. c. |
| Deduct 50 c. c. volumes Ba solution.. | 50 |
| | 6.127 c. c. |

This volume, when subjected to normal pressure, would be $= \frac{6127 \cdot 743{\cdot}5}{760} = 5993{\cdot}9$ c. c., and when reduced from 4° C. to zero would be $= \frac{273 \cdot 5993{\cdot}9}{277} = 5907{\cdot}3$ c. c. It required 21·1 c. c. oxalic acid solution, hence 3·4 milligrammes $CO_2$ (the equivalent of 3·4 c. c. oxalic acid solution) found in 5907·3 c. c. air at zero and 760 mm. pressure; 1 milligramme $CO_2$ at zero and normal pressure measures 0·5084 c. c., hence $3{\cdot}4 \times 0{\cdot}5084 = 1{\cdot}72869$ c. c. $CO_2$ found. To find the number of volumes of $CO_2$ in 10,000 volumes air, we have the following equation:

$$5907{\cdot}3 : 1{\cdot}72869 :: 10{,}000 : x.$$

$$x = \frac{1{\cdot}72869}{5907{\cdot}3} = 2{\cdot}926 \text{ volumes in } 10{,}000 \text{ volumes air.}$$

Estimations of carbonic acid in the air have been made in this laboratory several weeks under my direction, by Mr. B. F. Adams, who found that the principal source of error is the difficulty of ascertaining the correct temperature. If the apparatus is placed where it is thinly shaded, the temperature will vary ten or fifteen degrees C. in thirty minutes, according as the rays of the sun pass through the apparatus or as reflecting bodies are warmed. Even the temperature varies in different parts of the apparatus. When estimations are made, the temperature being below the freezing-point, and the barium solution is run into the apparatus, which necessarily has a temperature above the freezing-point, the air in the apparatus is warmed unequally. The difficulty is not removed by waiting until the fluid freezes, for during this time some air free of $CO_2$ may pass out of the apparatus by diffusion, and a false result be reached. With this apparatus, exercising the greatest care in determining the temperature and the atmospheric pressure, we have found that the quantity of $CO_2$ in the air is subject to slight variation at different times, but at present the number of estimations made is not sufficient to establish the maximum and minimum quantities during night and day, and during different seasons.

Indiana University, Chemical Laboratory,
Bloomington, Ind.

—*American Chemical Journal, vol. viii., No. 3.*

[NATURE.]

## PROFESSOR NEWCOMB'S DETERMINATION OF THE VELOCITY OF LIGHT.*

THE method selected for the important experiments described in the present memoir† is that known as Foucault's. The idea fundamental to it is that of the determination of the interval occupied by light in flashing from a revolving to a fixed mirror and back, by the amount of deviation produced in its return path through the change meantime effected in the position of the revolving mirror. The angle of deviation of the ray is double the angle of displacement of the reflector; to this angle corresponds (since the mirror rotates at a known rate) a definite fraction of a second, which is the time of luminous transmission across twice the measured distance between the mirrors.

But this theoretically simple means of ascertaining the velocity of light is complicated, in practice, with innumerable difficulties. A choice demanding the utmost nicety of judgment must be made between various conflicting conditions; sacrifice in one direction is the price of advantage in another; a balance has to be struck, giving the largest sum-total of facilities with the fewest and least intractable drawbacks. The plan finally decided upon by Prof. Newcomb was the result of much anxious deliberation; we hope to render it, in its main outlines, intelligible to our readers.

A fundamental condition of the problem is to get an image of the light-source absolutely coincident with the light-source itself, *so long as the movable mirror is at rest;* and this, whatever be the position the mirror is at rest in, provided only that it be such as to permit the rays sent out by it to return, after due triple reflection, to the eye. This requisite is secured by locating the center of curvature of the distant concave mirror in the axis of the revolving plane one. All rays emitted from this point toward the former will return along the same paths; differences of direction due to differing positions of the movable mirror will be eliminated by the return reflection; and there ensues a "stationary image" of the light-source, occupying, when visible at all, an invariable situation.

So far, all the operators by Foucault's method have been unanimous; but in the placing of the lens indispensable for the management and concentration of the light employed, a material distinction obtained between the plan of experiment chosen by Prof. Newcomb and that pursued by Prof. Michelson in his similar investigation at the Naval Academy in 1879 (see *Nature*, vol. xxi., pp. 94, 120). Fig. 1 represents in principle the arrangement adopted by the former, which was also that used by Foucault. In it the lens, L, is placed between the light-source, S, and the revolving mirror, A. Fig. 2 shows the disposition preferred by Michelson, in which the lens is interposed between the revolving and fixed mirrors. In both equally, S and M are, and for the purpose in view necessarily must be, in conjugate foci of the lens.

A disadvantage of the first form is that the measurement of any considerable deviations will be attended by uncertainties caused by the oblique passage through the lens of the return beams. It was, however, obviated in the experiments under consideration by the use of *two* lenses, one for the outgoing, the other for the incoming, rays. The second method (Michelson's) promises increased brilliancy of the image, which may, nevertheless, be regarded as outweighed by atmospheric and other impediments to its distinctness, as well as by the illumination of the field of view produced by the passage through it of some part of the lens with every revolution of the mirror. The method exemplified in Fig. 1 was then chosen by Prof. Newcomb as affording more or less calculable conditions; while No. 2 involved all the uncertainties of definition habitually besetting astronomical observations.

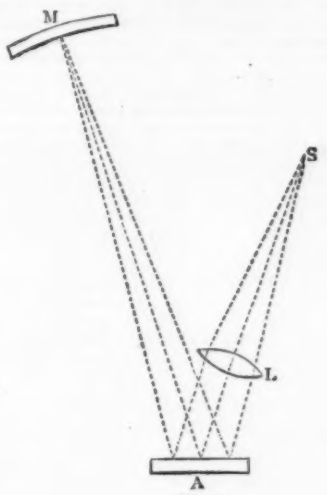


Fig. 1.

Let us now endeavor to realize the nature of the experimenter's immediate task. The precise measurement of an angle actually constitutes it. From the mirror, A, so long as it remains at rest, an image is reflected in a certain direction; but no sooner is A set rapidly rotating, than the same image is reflected in a slightly different direction. The amount of this difference—in other words, the angle of deviation—is the object to be ascertained.

Obviously, the first desideratum is to render the inevitable error of measurement comparatively small, by making the quantity to be measured large. Two roads are open toward this end. A high velocity can be given to the mirror, A, or a great distance can be interposed between A and M. By the first means, the angle rotated through in a given time will be augmented; by the second, the time available for the displacement of the reflector will be prolonged by the lengthening of the journey imposed upon the rays to be reflected. The difficulties hampering increased speed are purely mechanical, though none the less formidable; those in the way of a lengthened path are optical.

The preservation of light enough to keep the image bright and distinct is of paramount necessity for the avoidance of ruinous uncertainties in its measurement. Now, in Foucault's experiments, the object affording the image was the line of a reticule. It was dark upon a bright ground—a platinum wire relieved against a sheaf of sunbeams. But no perfectly defined image of such an object could be formed at any considerable distance; and we find accordingly that the utmost length by which he ventured to separate his mirrors was twenty meters. His entire apparatus was, in fact, contained in a single room. Hence, notwithstanding a speed given to his mirror of from 600 to 800 revolutions per second, the actual linear deflection of the return ray amounted to no more than seven-tenths of a millimeter. Chiefly by employing as his light-source an illuminated slit, the lucent image of which on a dark ground bore the enormous loss of light ensuing from the transportation of the fixed mirror to a distance of close upon 2,000 meters, Michelson was enabled to augment this deflection some two hundredfold. The resulting velocity for light of 299,910 kilometers per second was proportionately trustworthy, the error of the angular measurement upon which it immediately depended being estimated to be one hundred times less than in Foucault's determination. Prof. Newcomb's improvements carried him still further toward absolute accuracy.

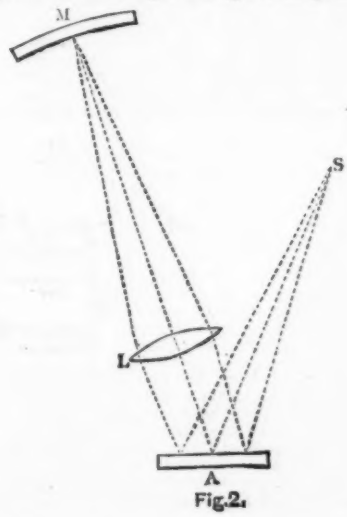


Fig. 2.

The details of construction of his "phototachometer" were decided on in the summer of 1879, and the instrument was completed by the Messrs. Clark in May, 1880. It consisted essentially of four parts—a sending and a receiving telescope, a revolving and a fixed mirror. Sunlight, thrown from a heliostat through an adjustable vertical slit at the eye-end of the sender, passed down the tube, which was bent at right angles to get it out of the way of the observing telescope, and, after reflection by a plane mirror at the elbow, passed out through the objective toward the revolving mirror. This was formed by a rectangular prism of polished steel, 85 millimeters in height, and with a cross-section of 37·5 square millimeters. The vertical faces constituting the reflecting area were nickel-plated, and proved of a remarkably durable, though not very high, polish. Motion in opposite directions at will was communicated by two air-turbines, acting one at the top, the other at the bottom, of the mirror, and serving, by a simple contrivance, each for the regulation of the contrary velocity imparted by the other. A wheel-work arrangement, by which an electric current was broken once for every twenty-eight revolutions of the mirror, gave the means of obtaining a chronographic record of its rate of going. Two fixed mirrors, mounted side by side on cast-iron stands, were employed to return the light sent to them by the revolving mirror. Each was about 40 centimeters in diameter, and had a radius of curvature of some 3,000 meters. The object-glass of the receiving telescope was (in the first instance) placed immediately under that of the sender, the former thus directly facing the lower, the latter the upper, section of the movable mirror. The two *tubes*, however, owing to the "broken" form given, as already mentioned, to that of the sender, made with each other an angle of 90°. Horizontal movement round a vertical axis coincident with that of the rotating mirror was possessed by the observing telescope, to which was attached a pair of microscopes for reading off the divisions on a horizontal divided arc fixed to a stiff frame at its further end. The amount of this horizontal motion of the telescope measured the deviation of the thrice-reflected sunbeam, and, by an immediate deduction, its velocity.

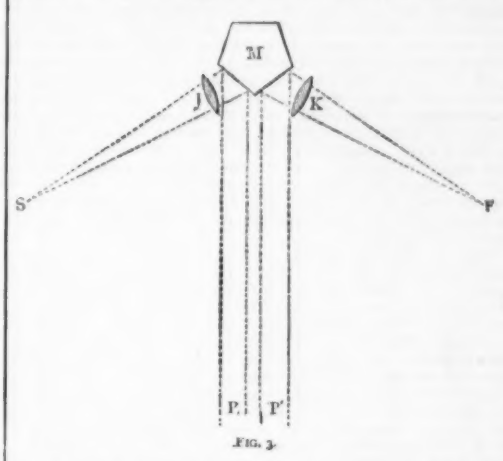


FIG. 3.

The site chosen for the erection of the apparatus was Fort Myer, on the south side of the Potomac, overlooking the city of Washington. The stationary mirrors, to and from which the carefully guarded rays performed their trips, were placed, to begin with, in the grounds of the Naval Observatory, at a distance of 2,551 meters from Fort Myer, but were in 1881 removed to a point at the base of the Washington Monument, at a distance increased to 3,721 meters. Some tentative experiments were undertaken on June 22, 1880; after a few days' trial, however, it was found that the wheel-work for counting the revolutions of the mirror was destroyed by the rapidity of the impressed movements. New wheels wore out almost before a set of readings could be obtained with them; until at length the Messrs. Clark, finding that no metal would stand the inflicted wear and tear, substituted *raw hide* as the material for the first wheel, a device which proved wholly successful. With the instrument thus modified, work was begun on August 9, and continued without interruption until September 20. The transportation of the fixed mirrors to the Monument station in the spring of 1881 postponed the commencement of operations to August 8; and their effective prosecution was then impeded by the discovery of a source of systematic error in a "torsional vibration" of the rotating mirror. That is to say, the steel prism employed to reflect the light, no longer, when its speed attained a certain point, revolved as an absolutely rigid whole, but *tended toward* the possession of different velocities in its different parts. Hence a slight twisting of its mass, producing vibrations round the axis of rotation, the effect of which was visible in the breaking up of the image of the slit into four separate images, one due to each of the faces of the prism. The persistence of this baffling symptom compelled a modification of the instrument, by which the sending and receiving telescopes could be respectively depressed and raised so as to alternate their positions, and the portions of the mirror they were directed toward. The mean of any two complete sets of observations made with the telescopes thus interchanged would be free, as Prof. Newcomb shows, from the effects of any probable form of torsional vibration.

No such effects, however, were apparent in the observations of 1882. This last series extended from July 24 to September 5, and were so nearly free from accidental differences that the probable error of a complete determination was scarcely more, under good conditions, than the ten-thousandth part of the whole.

* "Measures of the Velocity of Light made under the direction of the Secretary of the Navy during the years 1880-82," by Simon Newcomb, Professor, U. S. Navy. Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, vol. ii., parts iii. and iv. (Washington: Bureau of Navigation, 1885.)

† For the historical notice serving as an introduction to it, see *Nature*, May 13, p. 29.

Upon these, accordingly, the chief reliance was placed in the final discussion of results.

The announcement that Messrs. Forbes and Young had detected a difference of two per cent. in the rates of transmission of red and blue light prompted, at Fort Myer, a most careful watch for traces of color in the reflected image of the slit. But although, from a discrepancy of even one-twentieth that amount, a spectrum 15" in breadth must have ensued, the iridescent edges, which would infallibly have betrayed its presence, were not seen.

An important novelty in Prof. Newcomb's method was his use of opposite rotations and their accompanying opposite deviations. In his instrument the mirror, as already stated, could be made to revolve at pleasure, either from right to left or from left to right. Instead, then, of measuring, as had always previously been done, the deflection produced in the return ray by the change from rest to an ascertained rate of rotation, the object of his determinations was the total deflection due to extremes of contrary movement. The mode of experimenting was briefly as follows:

First, the valve was opened to the air-blast giving *negative* rotation, the receiving telescope being set upon some division near one extremity of its arc; the image of the slit was then accurately fixed, by the regulating agency upon the velocity of the mirror of the opposing air-current, upon the middle wire of the micrometer; the chronograph made its record of the rate of going, and the microscopes were read. This constituted what was called a "run," and occupied two minutes or upward. The telescope was next unclamped, and directed near the opposite end of the divided arc. *Positive* motion was given by opening the other valve, and the process of fixing the image and reading off repeated. A comparison of the two sets sufficed to determine the time spent by the light in passing to and from the mirrors on the other shore of the Potomac.

This method of contrary deviations is most strongly recommended by Prof. Newcomb to future investigators. It combines the two advantages of doubling the angle to be measured and of abolishing possible errors in the determination of the zero-point. In the present series, velocities, alternately in opposite directions, rarely exceeding 230 revolutions per second,* gave a total change of direction of nearly 8°. And this largeness of the measured angle materially contributed to enhance the accuracy of the results. Highly effective also, for the same end, were the elaborate precautions for darkening the telescopic field of view, and thus rendering the image of the illuminated slit more distinct. As their upshot, daylight was reduced to about one-thousandth its normal intensity. What was left only just sufficed to show the spider-lines without artificial light. The necessity for such precautions may be estimated from our author's statement that a concave mirror, of which the diameter should be one decimeter for each kilometer of distance, would receive only 1-60,000th part of the light reflected from the revolving mirror; while of that 60,000th part, only a small fraction could be practically turned to account, owing to the many sources of loss in reflection and transmission. Since, however, *two* fixed mirrors, each four decimeters across, placed at a distance of less than four kilometers, were employed in the operations at Fort Myer, the proportion of light there returned was rather more than double the above estimate. Prof. Newcomb appears to have been, on the whole, eminently successful in his optical arrangements. The imperfect definition which was the besetting difficulty of Michelson's experiments gave him little trouble.

The recent American determinations of the velocity of light, justly considered as of far superior precision to any others yet executed, give the following results:

| | | |
|---|---|---|
| Michelson, at Naval Academy, in 1879..... | 299,910 | km. |
| Michelson, at Cleveland, 1882..... | 299,853 | " |
| Newcomb, at Washington, 1882, using only results supposed to be nearly free from constant errors ..... | 299,860 | " |
| Newcomb, including all determinations... | 299,810 | " |

To these are added for comparison:

| | | |
|---|---|---|
| Foucault, at Paris, in 1862..... | 298,000 | km. |
| Cornu, at Paris, in 1874..... | 298,500 | " |
| Cornu, at Paris, in 1878 ..... | 300,400 | " |
| The same, discussed by Listing ..... | 299,990 | " |
| Young and Forbes, 1880-1881..... | 301,382 | " |

Prof. Newcomb's finally concluded result is that light travels *in vacuo* at the rate of 299,860 ± 30 kilometers per second. And the probable error of thirty kilometers, small as it is, has been liberally estimated. A determination so satisfactory of this important element goes far toward solving the problem of the sun's distance. Combined with Nyrén's constant of aberration, 20·492", it gives, for the solar parallax, the value of 8·794". The corresponding distance of 149·61 million kilometers, or 92,965,020 miles, agrees quite closely with Dr. Gill's result from the opposition of Mars in 1877, and exceeds by only 165,020 miles the mean deduced by Mr. D. P. Todd from earlier determinations of light velocity. No information as to the dimensions of the solar system which we are ever likely to get from a transit of Venus can approach in reliability the present conclusion.

Prof. Newcomb is so far from believing that the *ne plus ultra* of accuracy has been reached in his own remarkable experiments, that he appends to the detailed description of their method some valuable suggestions for its improvement. He had hoped, indeed, he tells us, to reach a concluded value exact to between five and ten kilometers, which, after repeated verification, might be available as a test of the invariability of standards of length. The further prosecution of the inquiry, however, he now leaves to any physicist who may be invited to the task by the promise of his advice and co-operation.

Fundamentally, he holds that the system pursued at Fort Myer in 1880-82 is preferable to any other yet tried. No known expedient for ascertaining the rate of transmission of light is comparable to that of its deflection, after a measured journey, by a moving mirror. The apparatus by which this plan was realized admits, however, in his opinion, of some amelioration in detail. The disadvantageous necessity, for instance, of appropriating a separate section of the reflecting surface to outward and homeward bound rays could be removed by the substitution of a pentagonal for a quadrangular prism, as shown in Fig. 3, where M is a section of the revolving mirror, J the object glass of the sender, receiving light from the slit, S, and throwing it in the direction, P, toward the distant reflector. On its return along the path, P', the ray is reflected from an adjoining face of the revolving mirror into the receiving telescope, K.

The closing words of the paper under review attest the unappeased aspiration toward accuracy characteristic of the successful investigator:

"A still further perfection of the method," its author writes, "which would lead to a result of which the precision would be limited only by our means of linear measurement, is, I conceive, within the power of art. It consists in placing the fixed mirror at so great a distance that the pentagonal revolving mirror would move through an arc of nearly 36° while the ray is going and returning. If a speed of 500 turns per second could be attained, the required distance would be thirty kilometers. Then, in opposite directions of rotation, the return ray would be reflected at phases of the mirror differing by the angle between two consecutive faces. The result would be that the receiving telescope would need to have but a small motion, and all the observer would have to measure would be the small angle by which the difference of positions of the mirror when the flash was received in opposite directions of rotation, differed from 72°. In the Rocky Mountains or the Sierra Nevada no difficulty would be found in finding stations at which a return ray could be received from a distance of thirty, forty, or even fifty kilometers, with little more dispersion and loss than at a distance of four kilometers through the air of less favored regions. It is true that the surface of the distant reflector would have to be increased in proportion to the distance, but it would not be necessary to make a single reflector of great size. A row of ten reflectors, each six or eight decimeters in diameter, might be sufficient to insure the visibility of the return ray."

A. M. CLERKE.

* Michelson's revolving mirror executed 256 turns in a second.

## THE PHONOPORE.

THE combination of the telephone and the telegraph on the same circuit is one of the latest developments of electrical communication. The following is the ingenious arrangement of Mr. C. Langdon Davies.

Mr. Davies has been working upon the problem for some time past, his first English patent dating from August, 1884, so that he is to be considered as one of the first in this particular field. Many experiments have been made by him, and his apparatus is now in a practical shape. All the developments of the phonopore are probably not worked out yet, because the instrument is capable of a variety of uses; but his telephone, telegraph, and the combination of these has been brought to a practical issue. It is these applications of the phonopore which we will now describe.

The "phonopore" itself derives its name from the Greek words *φωνη*, sound, and *πορος*, a passage. It is a simple appliance which may be described as a wire condenser, that is to say, a condenser in which the plates or armatures are of insulated wire laid side by side. Its nature may also be easily understood by likening it to an induction coil in which the primary and secondary circuits are employed like a condenser, or in other words, with one end of the wires free, so that there is no circuit for the current. More accurately, it consists in the ordinary form, at least, of two silk-covered wires bound together parallel to each other by an outer covering of silk, like a two-wire cable, and wound in the same position on a bobbin. Two No. 30 B. W. G. copper wires, each 500 yards long, wound together on the bobbin, will, for example, make a phonopore; but of course the dimensions and form of the apparatus are varied to suit the special purpose for which it is intended. The wires, for instance, may be of a different gauge, length, or material, and they may be twisted together in a strand instead of laid parallel, and so on. In the phonopore, however, we have two long conductors in close proximity but insulated from each other, and the electrical impulses in one are transmitted to the other with apparently no loss of power, at least for practical purposes. The metallic circuit, at the same time, is of course broken between the wires, by the intervening insulator.

Mr. Davies has found that this apparatus, while stopping the passage of the ordinary telegraph signal currents, allows the vibratory telephone currents to pass, and on this fact is based the system of simultaneous telegraphy and telephony which he has brought out.

This property of the device in question obviously enables him to superpose telephonic currents on a telegraph line and to receive them at the distant end, or any intermediate point, or to translate them to another line, without interfering with the working of the telegraph.

In order to explain the system better, we shall begin with a simple phonopore line, however, such as is sketched in Fig. 1, where PT, PT are the phonopore

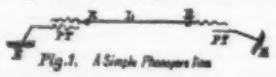


Fig. 1. A Simple Phonopore Line.

transmitters, the wavy lines showing the primary and secondary wires of the phonopores themselves; RR the phonopore receivers, to the line, and E the "earths." This is a line which can be worked either by telephone alone or by the phonoporic telegraph, which Mr. Davies has invented, and which we shall describe later on. It may be asked what advantage there is in using the phonopore for simple working in this way. Mr. Davies, we understand, finds that the introduction of the phonopore in the telephone circuit tends to eliminate induction noises produced by neighboring lines. As for the phonoporic telegraph, it is in itself a novel mode of telegraphing by means of vibratory instead of continuous currents, and may therefore be held to possess the peculiar advantages of that method, some of which were set forth in our recent article on Captain Cardew's system as applied to military telegraphy. The chief advantage of vibratory currents appears to us to lie in the fact that they seem better capable of traversing badly insulated lines, and perhaps also lines of very high resistance, with smaller battery power than ordinary signal currents.

Fig. 2 is a sketch illustrating a composite line for

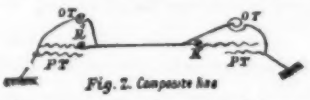


Fig. 2. Composite line

working ordinary telegraphs and phonopores simultaneously. Here PT is, as before, the phonopore transmitter, OT is the ordinary telegraph, and R the phonopore receiver. Fig. 3 is another arrangement,

Fig. 3. Composite line

where there is an ordinary telegraph line from A to B, and another from B to C. By the arrangement shown, a phonopore service is worked from A to C without interfering with the ordinary service. Fig. 4

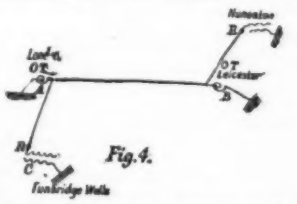


Fig. 4.

shows a scheme by which an ordinary telegraph line can be worked from A to B, while an independent phonopore service is worked from C to D. It will be understood that the phonoporic vibratory telegraph may be worked with the ordinary telegraph, just as the telephone can be worked with the latter.

Turning now to the arrangement of the apparatus itself, we have in Fig. 5 a phonoporic telephone trans-

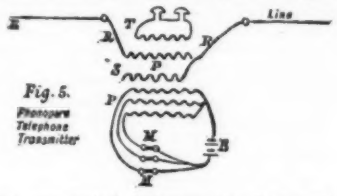


Fig. 5. Phonopore Telephone Transmitter

mitter, F, connected between the line and earth, E. Each layer of the "primary," P, of the phonopore coil is in circuit with the battery, B, and a separate microphone, M; all the layers being connected conjointly to the poles of the battery as shown. The "secondary," S, of the phonopore is connected to the receivers, RR, as shown; or the receivers may be connected, not to the secondary wires, but in a "tertiary" wire, T, as shown, wound outside the other wires.

The bobbins of the receiving telephones may themselves be wound with a phonopore.

These arrangements of the telephone circuit are designed by Mr. Davies to increase the power of the latter, and diminish the effect of the telegraphic currents in it. We come now to the arrangement of the phonopore telegraph as shown in Fig. 6, which repre-

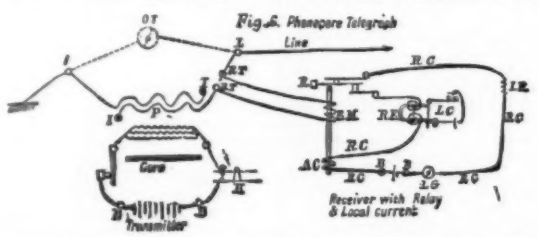


Fig. 6. Phonopore Telegraph

sents the installation at each end of the line; E being the "earth" connection as before, and L the line terminal. Between these two points the apparatus is joined up; the ordinary telegraph, OT, being joined direct, while the phonoporic telegraph is connected through the phonopore, P.

Dealing first with the transmitter, we have the transmitting battery, BB, in circuit with a Morse signaling key, K, a vibrating reed interrupter, R, and the coil which actuates it wound on the core, which is shown separately for the sake of clearness. The magnetism of the core keeps the reed in vibration, making and breaking the current by the well-known action seen in electric bells of the "trembler" class. The reed or interrupter, battery, and Morse key are all in circuit with the primary of the phonopore, which is shown with three wires. It follows then that the intermittent current set up in this circuit by the vibrating reed, and broken up into long and short Morse signals by the Morse key, acts through the phonopore from its primary to its secondary wires, the ends of which are insulated at H. The impulses of the secondary traverse the line to the distant receiver.

The receiver, which, like the transmitter, is of similar construction at both stations, is connected at RT, RT, which are the receiver terminals. It consists of a vibratory relay, which is operated by the phonoporic impulses or vibratory signals from the line, and in turn works a telegraph instrument, such as the Morse

or sounder, by the aid of a post office relay and local battery. The way in which the vibratory signals work the relay is very interesting in itself, but it will be best understood, perhaps, after we have described the parts of the relay circuit, RC. This comprises a battery, BB, which re-enforces the action of the line impulses on a vibrating reed interrupter, R, when these impulses are passed through the electro-magnet, EM. This is effected by a second auxiliary coil, AC, on the core of this magnet. The receiving coil, EM, is simply connected to the receiving terminals, RT, RT, while the auxiliary coil, AC, is in circuit with the auxiliary battery, BB, the reed interrupter, R, and the coils of the relay electro-magnet, RE, shown, which influences the tongue of the relay in opening and closing the local circuit, LC. A resistance, LR, is connected in the receiver circuit, RC, to assist in maintaining the constancy of the battery, and a galvanometer, LG, is also inserted to act as a current indicator.

Now the vibratory impulses from the line passing in the coil, EM, sets the reed, R, vibrating, thereby interrupting the auxiliary current in the coil, AC, which re-enforces the effect of the impulses from the line. A vibratory current also traverses the coils of the relay electro-magnet, and the tongue of the relay closes the local circuit every time a signal passes on the line. The relay tongue operates in a continuous manner, not vibratory; that is to say, the tongue keeps the local circuit closed, while the vibratory signal current traverses the electro-magnet, EM, or, in other words, the relay responds to the signals of the line. The receiver or recording instrument in the relay local circuit, whatever that instrument be, is actuated and gives out the message. The vibrating reed, R, has more than one contact to make and break while vibrating, as will be seen by reference to the figure, and the contacts themselves are small hammer heads on springs in place of rigid contacts.

By this arrangement Mr. Davies can transmit comparatively feeble phonoporic impulses over a line, and cause them by re-enforcement to operate ordinary sounders and other telegraph apparatus.

At his offices in 110 Cannon Street, E. C., Mr. Davies has a variety of apparatus installed and working on artificial lines, so as to show the apparatus in action. For example, two Spagnoletti extra sensitive needle instruments are connected through a resistance of 2,000 ohms and worked satisfactorily with a battery of sixteen Leclanche cells, while a phonoporic telegraph is worked simultaneously with them by a battery of four similar cells. On increasing the resistance of the line to 25,000 ohms, the phonoporic telegraph still continues to send messages, while the single-needle telegraph refuses to operate. This demonstration shows how the vibratory currents overcome the resistance of a trying line.

Another installation of Mr. Davies consists of a phonoporic telegraph on a line made up of twelve electro-magnets of a total resistance of 2,500 ohms, a quarter megohm (25,000 ohms), and an artificial line of 25,000 ohms, making a grand total of 277,500 ohms. The phonoporic telegraph operates through this, and works a post office relay connected to a local sounder. Through the same resistance a phonopore telephone is also worked; the battery in this case being two Leclanche cells.

These experiments, which we have ourselves seen, are sufficient to show that the property of overcoming high resistance is possessed by comparatively feeble vibratory currents, a property which renders the phonopore capable of working on badly insulated and poorly conducting lines, when ordinary telegraph apparatus would fail. Moreover, besides its power of working simultaneously with an ordinary telegraph, or a telephone on the same wire, the phonoporic telegraph can be developed into a multiple telegraph by the well-known device of making the reeds vibrate to a particular note so as to send vibratory currents of one particular period. Several of these reeds, with their attendant transmitting and receiving apparatus, may therefore be used on one line, each sending its own particular vibratory impulses into the line; and these impulses would vibrate them on harmonic reeds at the other end of the line, thus working their own local receiver. In this way a number of independent phonoporic messages might be sent together on the same wire.—*Engineering.*

## CLERC'S AUTOMATIC COMMUTATOR

THE object of Mr. Clerc's automatic commutator is to substitute one incandescent lamp for another, should the latter's filament break, and to thus prevent a period

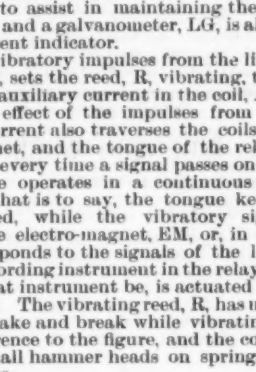



FIG. 1.—SECTION OF CLERC'S AUTOMATIC COMMUTATOR.

of darkness, which might sometimes prove annoying, or even dangerous.

It is applicable wherever there is a single lamp burning, in apartments, water closets, halls, and other places.

Fig. 1 shows how the apparatus is constructed, and Fig. 2 (from *La Nature*) shows its application. A vertical electro-magnet, A, is placed in the circuit of the lamps in use. In the interior of this electro there freely plays a tubular armature of thin sheet iron, which terminates below in two rods, C, that dip into mercury cups, D. When the lamp, E, is burning, the current passing into the electro-magnet lifts the wire cylinder, and the circuit of the lamp in reserve is open. When an accidental extinction occurs, the rods, C, dip into the mercury, and the circuit of the lamp in reserve, F, is closed. The light is thus not appreciably interrupted. At every normal extinction of the lamp, the suppression of the electric circuit lets the soft iron armature fall. When the circuit is closed for lighting, the current passes for an instant into the lamp in service and into the one in reserve; but, as the armature is at once raised by the passage of the current into the bobbin, the lamp in reserve is immediately thrown out of circuit. The caps, D, are so arranged that the mercury cannot overflow. The lamp in reserve may be mounted upon the same support as the one in service; but, if such an arrangement has not been provided for, it may be placed in any suitable spot in the room to be lighted.

In order to keep the cylindrical armature constantly suspended, it requires a bobbin of a certain resistance. Mr. Clerc has endeavored to reduce such resistance as much as possible by diminishing the weight of the armature, and has thus succeeded in reducing the consumption of electric energy, which always remains below one watt.

The same arrangement is applicable to lamps in derivation, mounted for tension upon a distributing cir-

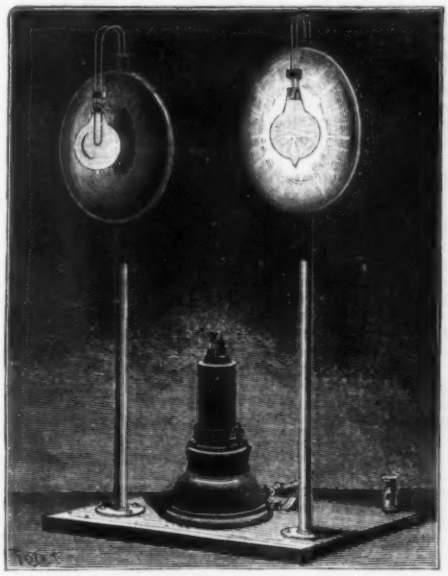


FIG. 2.—APPLICATION OF THE APPARATUS.

cuit of constant intensity, in order to prevent all the lamps of a series from burning one after another when a single one chances to give out. When it is desired to light the two lamps at once, it suffices to place at the entrance or exit of the bobbin a small interrupter to temporarily suppress the operation of the apparatus and thus leave both lamps in circuit.

## THE SOARING OF BIRDS.*

By I. LANCASTER.

THE flight of birds has never been completely explained by reference to known mechanical laws. The work done in their translation must be sufficient to prevent the gravitating force of the bird's mass from carrying it to the ground, and also to overcome the resistance of the air to their passage through it. Muscular effort in wing motion is not competent to the task in all cases, while soaring, a motionless wing flight, presents a complete mystery. It is a thankless task to inquire with any nicety into the ability of flapping, while the largest and heaviest birds habitually translate themselves with no wing motion whatever. It occurred to me, thirty years ago, that the mechanical world was entirely at fault in this matter, and that the activities in progress were not what they were supposed to be. This opinion was confirmed as time wore on, and the final conclusion of the whole case demonstrated the correctness of the first surmise.

Men's judgments of the flight of birds are mistaken judgments. The direction which investigation has taken has been a wrong direction. The forces involved in the phenomenon do not act as they have been supposed to act. I propose to present the subject in the order in which it has been developed in my own mind as briefly as possible.

My attention was first seriously directed to this matter by witnessing the flight of whooping, or sandhill, cranes. The movements of the carrion-eating vultures or turkey buzzards had been frequently seen with admiration, but never under circumstances where long continued soaring or fixed wing flight was unmistakably carried on. The cranes were at this time abundant on the prairies of Illinois during the summer season, breeding there and proceeding to a warmer climate on the approach of winter. Their habit of flight during the season was by slow flapping of about one stroke per second. They would weigh about twelve pounds, with six square feet of wing surface, averaging two pounds to a square foot.

About the middle of October, their migration commenced, and the initiatory movements were generally made in couples. After a great outcry and series of ground and lofty tumblings, and swinging of their long legs in the most ludicrous fashion, they would vault into the air, and rise by means of slow flappings, in great circles, moving spirally upward as they went round, until a height of three or four hundred yards was reached, when suddenly their pinions would be stretched rigidly to their utmost and the upward spiral flight continued to an altitude often beyond the limits of vision, but generally terminating at a height of one or three miles. When the elevation satisfied them, a vigorous whooping was once more indulged in, their clear, resonant tone being plainly heard below. If all was ready for the voyage, after an hour spent in trumpeting adieu to the vicinity, they would swing off on a tangent to the south. If not prepared, they would presently return to the earth by the same method, dance for an hour in the most furious fashion, and exhibit not a trace of fatigue from the effort of the aerial journey. Indeed, no effort on their part had been discernible. Examination of the wing surfaces by a good glass, subsequently made, could distinctly separate each feather terminating in the rear edge of the wing, there being no mingling of the lines such as there must have been had the pinion been in motion. The atmosphere seemed perfectly calm, the long fibers of the cottonwood filling the air for a seemingly interminable distance upward, all as motionless in the Indian summer sky as if petrified. Here was something loudly calling for explanation. How was it done? This question became more and more emphatic as time wore on. I ransacked the mechanical authorities. No help was obtained. I encountered proffered solutions on all sides. They were worthless. They either contradicted the facts, gave a solution more difficult than the original mystery, or submitted pure guesswork. Neither of these methods were satisfactory.

The account given by Charles Darwin of soaring, in his "Naturalist's Voyage around the World," was the only clear statement of the facts in the case that I was able to find. His observations were made upon the condors of South America, and are, as usual with the writings of Darwin, extremely interesting. He offered a provisional explanation only, which was to hold merely in the absence of a better one.

Whenever time could be spared from other duties, I employed it in endeavoring to obtain the facts of this method of flight. Observations were confined to the United States east of the Mississippi River, and included almost all the birds found in that region. The most valuable information acquired down to the year 1876 was of the nature of pretty clear ideas in regard to methods of conducting the investigation; and finding myself in that year out of business, and free to pursue the task of penetrating the soaring secret, I went to the gulf coast of south Florida, below Tampa Bay, and resided there for five years, continuously engaged in this matter. What was found there I very briefly propose to tell.

From Tampa Bay to the capes, the soaring birds are found in profusion. These consist of buzzards, frigate birds or man-of-war birds, various cranes, among which are found the sandhill cranes, gannets, eagles, pelicans, gulls, herons, and others of less importance. Every sort of bird that can live on fish seems to be found here, as the waters swarm with innumerable species of the finny tribes. The many shallow bays and inlets which line the coast furnish extensive breeding grounds for them, and the tepid waters of the gulf are favorable to fish life. The larger kinds prey upon the smaller, and the porpoises, sharks, devil fish, stingarees, and a host of voracious feeders are perpetually passing in and out of the passes with the tide, wounding and killing many which they do not eat, and which, when stranded on the flats at low tide, furnish food for the buzzards, which are seen everywhere.

The whole country is dead level, no hills nor valleys, piles of shells being the highest met with. The sea breezes are delightful, and well-nigh perpetual. The climate is, to my sensation, simply perfect both summer and winter. The land is absolutely sterile to anything but the tough, innutritious growths of sawgrapes, air plants, palmettoes, long-leaved pines, and innumerable dwarf vegetations, in which there is nothing that a man can live on, so that the problem of life there is to find something to eat. Cats, opossums, fish, and birds that live on fish, have everything pretty much their own way.

As a result of this state of things, the people are not plenty, so that the birds, being undisturbed, were during my stay almost oblivious of the presence of man, allowing themselves to be closely approached without fear. Certainly southern Florida was a good place to study the soaring birds. In the first place, it was imperative to find whether the direction of the wind was horizontal or moved with an upward trend as it met the coast line. A feathered arm balanced horizontally was used, and effectually established the level motion of the coast winds. Even ten feet above the forest tree tops the wind moved on level lines, and seldom indeed did the indicator show deviation from horizontal in wind of any locality. As the matter finally ended, all this careful work was utterly useless, as wind has nothing whatever to do with bird flight, as such—meaning by wind, motion of the air relatively to a fixed point connected with the earth. Motion of the air relatively to the bird may be termed wind, but in a different sense, as it is entirely possible for one to exist without the other.

The buzzards would habitually rest in the sea breeze along the inner or bay coasts between thirty and fifty feet above the water, facing the wind, for hours at a time on motionless wings. They were birds of from four to six pounds weight, with an equal number of square feet of wing surface. They are a much larger bird than those farther north, with feathered necks and finer appearing. I watched a score of them on one occasion for fourteen consecutive hours, during which time not a dozen flaps were made for each bird. They did not move fifty feet from one locality during that interval. These birds would frequently start from their position of rest in the wind and move across the bay on fixed wings to the outer beach, a distance of three miles, and return in the same motionless manner. Where the dead tree selected as a roosting place stood near the beach, with nothing to break the flow of the incoming breeze from the gulf, these birds would be lifted from their perch on their long outstretched wings as gently as the fall of a feather, at first, with increasing speed, either horizontally against the wind or at any angle of the quadrant from horizontal to vertically upward. When resting in the breeze, a bird would at long intervals rise vertically upward for a mile, and return to the flock below without making an observable change in its immobility. During high or rough winds, these birds sought their roosting places, not that they could not soar in such winds, but that

* Abstract from a paper read before the American Association, Buffalo, August, 1886.

the effort seemed greater, which interfered with their do-nothing habits.

The frigate bird had greater power of translation than any others on the coast. Their movements were simply marvelous, as though they were endowed with the powers of magic. I have witnessed them move on fixed wings against a southeastern tempest of wind, certainly of not less than eighty miles an hour, with a velocity which I judged to be equal to that of the wind itself. A bird killed by a party of specimen hunters weighed six pounds, with wings eleven feet from tip to tip. When the wind is strong, they rest in it with partially flexed pinions, which at times are curved so far beneath the body as to meet in a continuous circle. I have reason to believe that these birds remain high in air for a week at a time without food, and without descending from their airy position.

A closer stand of observation being desirable, recourse was had to the arts of mimicry, and, procuring a sheet of light cotton fabric sufficiently large to entirely envelop my person, it was painted a mixture of green and brown shades, to resemble the top of a pine tree. This disguising dress proved an admirable device, and it was used on many occasions in various localities on the coast in the vicinity of the roosting and breeding places of the birds. Perched in a tree top which had been arranged for comfort at leisure, clad in this painted robe, with the birds lazily resting in the breeze, all about, totally oblivious of my presence, I could gaze on the mystery going on before my eyes with critical attention, but with not one jot of understanding. The more I looked, the more impenetrable became the secret. The mechanical laws governing matter and motion seemed to be set at defiance, and after nearly five years of this kind of work, the subject took on a positively uncanny aspect.

The gannet, when a tree top near their breeding places was occupied, would float within a foot of my face as rigidly immovable as a board. They have alighted on my head with their toes in my mouth. They would weigh as much as eight pounds, with about four or five square feet of wing surface. A stiff breeze was required to float them if they remained in one place. They seemed to sleep, as their eyes were closed for an hour at a time. They were in a position of perfect equilibrium. I have gently pushed them with a stick in various directions while they were thus balanced, and any effort at all would move them in any direction until they would waken, which they were not long in doing. A peculiarity attending an upward push was as profound a mystery as anything connected with these birds at that time. Such a push caused backward motion to a greater extent than direct upward motion. An inch upward would cause two or three inches backward displacement. A hard push would cause them to drift with the wind for ten or twelve feet before they could readjust themselves, when they at once left that locality. This was afterward made entirely plain. Another feature which caused much perplexity was the different appearance of the front and rear part of the under side of the wing in regard to the roughness and smoothness of the feathers. The front part of the wing from the body to the tip seemed rough, as though the wind were passing over it from rear to the front, while the other half from the center to the back edge was smooth, as it naturally would be in the wind current. The dividing line was perpetually shifting either to the front or rear. Its motions were very irregular, and in some lights seemed iridescent. Sometimes almost the entire under surface seemed roughened, and then in an instant be smooth. The position of the wings of all birds while in the act of soaring was on an incline highest in front. The heavier the bird, the more the inclination. These gannets would float at an angle of about fifteen degrees with the horizontal. The frigate birds at very low inclination, often seemingly nearly level but all birds had the power of varying their incline to suit their purposes. The position of the wings in reference to the body also widely varies. The buzzard's slant upward, with the tips a foot above the body, the frigate bird's like a flattened letter *n*. The gannets float with their bodies higher than their wings. So do the herons, while the sandhill cranes will be nearly level.

It was found that the soaring flight could be carried on in any condition of air, either of wind or calm, could proceed either with the wind or against it or at an angle of obliquity to it, and either up or down. Calm air is the best condition for rapid and steady flight. The birds generally move in circles in still air, excepting when migrating or traveling away from home. This is done that they may be in the air and still not leave their own locality. The frigate birds habitually circle round and round, high over the coasts of southern Florida, and during times of calm are rarely out of sight.

Soaring can only be accomplished when bird and air are meeting. In still air this blowing against the advancing bird is produced by motion of the bird in any direction. If the bird advances against the wind, the conditions are complied with; and if going with the wind, its motion is faster than the wind. A moment's thought will show that motion of air relatively to any fixed point is irrelevant to the soaring activity. Soaring is motion related to bird and air alone, and wind is a motion of the entire material system of soaring as a whole which equally carries all the parts. A bird in air is similar to a steamboat on the water. The boat's power to move in the water is derived from itself, and is measured by the number of lineal feet of water passing beneath it in a given time. Likewise, the bird's power to move in air is derived from itself, and is measured by the lineal feet of air passing beneath it. When either the bird or boat does not act on the air or water by force derived from themselves, they are at rest with air and water, and therefore move with it. It is evident that both bird and boat may be carried from point to point on the earth's surface by this motion of the medium in which they rest, themselves being quiescent, but this sort of motion has little to do with either bird or boat navigation.

The facts exhibited by the soaring birds have now been sufficiently detailed to suit the purposes of this paper. An explanation of those facts is still required. The multitude of proffered solutions which I had found scattered about in the current literature of the day successively broke down when confronted by the facts. None of my own making were more fortunate. I had succeeded in doing nothing more than to clearly define what was going on. The delusion that air in motion relatively to an observer gave motive power to the bird was avoided, for the reason that calm air was the very best condition of atmosphere for this activity. Hypotheses framed from the examination of one species of bird were abandoned when another species was investigated. Upward trending currents of air, unseen tides of the atmospheric ocean, or any conceivable activity of air on bird which was not of the nature of a reaction, were dismissed as simply unworthy of attention; for sandhill cranes would lift themselves spirally upward to a height not less than 10,000 feet, and buzzards would translate themselves for three miles at a stretch in air so calm that swan's down would fall vertically, and a tissue paper balloon ascend without being deflected one degree from perpendicular. However much individual birds might vary in weight and wing shape, and surface, they all agreed in being flat planes inclined more or less to the horizontal, and the ever recurring question whence is derived the motive power to push this inclined plane on the air at length filled me with dismay, because of a dawning conviction of the helplessness of discovering a solution. The limitations of time will prevent me from going into an analysis of the mechanical forces engaged in the activities producing the soaring birds. This must be deferred to a more suitable occasion. I will, however, briefly mention a few very simple experiments which serve to carry the soaring phenomenon into the region of inert substances. If a bird can float indefinitely in calm air without using muscular exertion, being for mechanical purposes as rigid as a board, then a board or metal body if of the right shape and position ought to be able to do the same thing. In construction, it must preserve the essential features of the bird's wing. It must have the under surface rough to motion from rear to front, and smooth from front to rear. It must have the front ledge on the under side. It must have the elastic feather tips and be longer than it is wide, and, if it closely imitates the birds, must have from one to three pounds weight for each square foot of surface.

I constructed floating planes, which, for lack of a better name, I have termed effigies, and which are an example in point. I have made scores of them. They would draw into the breeze from the hand, and simulate the soaring birds perfectly, moving on horizontal lines, or on any inclination to a vertical. They would float in the best winds with neither ledge, rough front surface, nor rear curve, if very nicely adjusted; but one of this construction I never induced to pass beyond the limits of vision, as the equilibrium was so very delicate that a little inequality in the wind current would capsize it. With the addition of a serrated front surface and ledge, they would float in any reasonably steady breeze. By using a pendant of fine shot, and a double bag with a neck so constructed that the shot would fall in a few seconds from the upper to the lower bag, including the plane as it did so, continuous motion in calm air can be obtained. I have floated these planes from the lantern of Egmont lighthouse, of 150 feet high, and they might be still floating, provided that no storm had been encountered by them. But the most interesting device illustrative of the case which I was enabled to make consisted of a balanced arm rotating in a horizontal plane after the manner of a turnstile or children's merry-go-round. The frigate birds can be seen any calm day over the lower Florida coasts going round and round in their interminable circles on fixed wings the whole day long, and the whole night long too, provided you could get them in a line with your eye and the full moon. Then a plane of the weight and dimensions and position of a frigate bird ought to move in the same manner if similarly placed. Not being able to try the experiment a mile high in free air, I did the next thing, and tried it on the surface of the earth at an elevation of about six feet. The rotating arm was made as light as possible, its only function being a directive one. At first, a diameter of eighteen feet was used, with planes fourteen by thirty inches. I was engaged for two or three months on this device without success. It would not imitate the birds, and move continuously. I found at length that on account of the more rapid motion of the outer ends of the planes than of the inner ends, the outer ends would climb the inclination faster than the inner, thus crowding the air away in the lateral motion. To remedy this defect, the planes were made winding, so as to make the inclination of the inner end steeper. This was a great advantage, but I did not get rotary motion. I was confident of some error in the construction, but could not at that time locate it. It, however, occurred to me that I had never observed a soaring bird swing in circles less than a hundred feet in diameter, and they passed in curves generally much greater than this. I made a haphazard trial by extending the arms to a diameter of ninety-four feet, and a plane about twenty-four by twelve feet, and had splendid success the first trial. It would only operate in calm air, but on one occasion it traveled for three days without halting; that is, I presume it did not halt. I watched it through one night, but slept the next night, and in the afternoon of the third day a slight breeze stopped it. It would move around at once in still air whenever started.

There remains a single further experiment worthy of mention. When the question arises of applying their mechanical activities to the problem of artificial air navigation, it becomes pertinent to know whether the relation of weight, shape, and position will hold with a mass so great as the body of a man, and the device required to sustain him, as they do to produce the activity of soaring flight, with less weights. A large plane was constructed, some ten by thirty-five feet, and held by ropes. It sustained its own weight together with any person with ease. It was of the rudest possible manufacture, extremely unsteady, and required a wind of about thirty miles an hour to float it. It served to settle the question that heavy weights and large areas were no detriment to soaring flight. This was to be expected. The greater the area, the more intense the pressures under the plane, and hence the more decided the forward thrust.

This whole field is open for experimental investigation. It has scarcely been touched by myself. The task of dispelling the fog was so great that both the time and means at my disposal for prosecuting the case were exhausted. I left the peninsula of Florida five years ago, with the expectation of speedily returning to complete a work which was by no means ended. I have not been able to do so thus far, but am entirely convinced that a region of atmospheric dynamics of the most important character, hitherto not explored, awaits the mechanical pioneer.

## PARISIAN CARMINE.

THIS is a favorite cosmetic at the present time, and is made as follows:

Two parts of the finest quality of carmine found in trade are mixed carefully with one part of the best French chalk (talc) in the finest possible powder. The latter ingredient is not added as a sophistication, but because it assists or facilitates the application of the carmine to the face. In the shops at Bordeaux the packets of this preparation are labeled "Carmin Parisien."

A CATALOGUE containing brief notices of many important scientific papers heretofore published in the SUPPLEMENT, may be had gratis at this office.

THE
# Scientific American Supplement.
PUBLISHED WEEKLY.

**Terms of Subscription, $5 a year.**

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

**MUNN & CO., Publishers,**
**361 Broadway, New York, N. Y.**

## TABLE OF CONTENTS.

PAGE

I. CHEMISTRY.—New Apparatus for the Estimation of Carbonic Acid in the Air.—By THOMAS C. VAN NUYS.—A full description with figures and calculations of an analysis of an accurate method for effecting this hitherto difficult determination.—1 illustration.. 8898
The Posometrical Drop Counter.—A description of Jannin's new drop measuring and counting bottle, that gives drops of accurately determined size..... 8898

II. CIVIL ENGINEERING.—The Balance Water Motor.—An extremely simple and easily constructed motor that is claimed by the inventor to surpass the turbine or overshot water wheel in economy, a return of 93 per cent being claimed for it.—Full calculations are included.—1 illustration..... 8903
The Luis I. Bridge at Oporto.—A detailed account of the great bridge across the Douro, with a span of 525 feet.—The structural features, platforms, arches, piers and arch, and description of the process of erection.—The illustrations include elevation, plan, and sections of the structure.—4 figures..... 8899
The Water Supply for the City of New York.—By R. D. A. PARROTT.—An elaborate study of the proposed Quaker Bridge dam, and the results to be anticipated from its completion.—This is one of the most important contributions to the literature of this subject.—It shows how evil rather than good is likely to be the outcome of the proposed work, and suggests the Catskill Mountains as a source of water supply..... 8900

III. ELECTRICITY.—Clere's Automatic Compensator.—An apparatus for substituting a new incandescent lamp for a broken one, thus avoiding a source of possible danger and of inconvenience incidental to electric lighting.—2 illustrations..... 8901
The Phonopore.—Detailed account of the new device for including telephone and telegraph on the same circuit.—An arrangement devised by Mr. C. LANGDON DAVIS by which this long sought object is attained.—6 illustrations..... 8900

IV. ENGINEERING.—The Building of Crank Shafts.—A technical and general description of the building of the largest class of shafts.—The shrinkage of the webs on the shaft, of the pins in the crank webs; turning and truing of the whole with measurements of the completed structure.—11 figures..... 8899

V. MARINE ENGINEERING.—Raising the Wrecked Steamship Pearl of the Realm.—Paper read before the Institution of Mechanical Engineers by Mr. THOS. W. WAILES.—A full account, giving all details of this remarkable feat in submarine engineering.—The raising from the bottom and towing to port of a vessel 300 feet long containing a cargo of coal.—6 illustrations..... 8897

VI. MATHEMATICS.—Radii of Curvature Geometrically Determined.—By Prof. C. W. MACCORD, Sc. D.—No. III.—The Archimedean spiral.—A full discussion of the problem of determining the radius of curvature of this curve.—A continuation of Prof. MacCord's series of articles.—2 diagrams..... 8894

VII. MISCELLANEOUS.—Sawing of a Large Log of Poplar, yielding over 3,000 feet of lumber..... 8897
The Soaring of Birds.—By I. LANCASTER.—Paper read at the meeting of the American Association for the Advancement of Science, Buffalo, August, 1886.—A paper that caused one of the sensations of this meeting and provoked much discussion..... 8901
American Association for the Advancement of Science.—Buffalo Meeting, 1886..... 8905
The Parisian Fire Department..... 8895

VIII.—PHYSICS.—Prof. Newcomb's Determination of the Velocity of Light.—By A. M. CLERKE.—A full account of this classic investigation, one of the finest physical demonstrations of this day and country.—Comparison of Prof. Newcomb's results with those of other physicists are included in the article.—3 illustrations..... 8899

IX. TECHNOLOGY.—Apparatus for Manufacturing Carbureted Air Gas.—A full description of an advanced process for this work.—Apparatus suitable for use in isolated localities where coal gas is inaccessible.—An interesting feature of this apparatus is that it is run by a gas motor actuated by the gas produced, and so requires no winding up and no external power.—1 illustration..... 8907
Cleaning Paint Brushes.—A note of interest to painters..... 8905
General Principles Governing the Action of Carriage Wheels.—JAS. G. CAMERON.—A scientific treatment of this subject, of interest to all advanced carriage constructors, the mathematics of the subject being fully developed.—3 illustrations..... 8902
How to Make Printing Plates or Engravings by Etching.—Gillotage.—An exhaustive description of this well known and recently devised process, giving full details of thickness of plates, solutions used, biting process, etc.—2 illustrations..... 8906
The Breaking of Grindstones..... 8904
Artificial Stone Making..... 8905

# PATENTS.

In connection with the **Scientific American**, Messrs. MUNN & Co. are solicitors of American and Foreign Patents, have had 42 years' experience, and now have the largest establishment in the world. Patents are obtained on the best terms.

A special notice is made in the **Scientific American** of all inventions patented through this Agency, with the name and residence of the Patentee. By the immense circulation thus given, public attention is directed to the merits of the new patent, and sales or introduction often easily effected.

Any person who has made a new discovery or invention can ascertain, free of charge, whether a patent can probably be obtained, by writing to MUNN & Co.

We also send free our Hand Book about the Patent Laws, Patents, Caveats, Trade Marks, their costs, and how procured. Address

**Munn & Co., 361 Broadway, New York.**
Branch Office, 622 and 624 F St., Washington, D. C.